POPULATION DYNAMICS OF YOUNG-OF-THE-YEAR BLUEGILL

Technical Bulletin No. 127
Wisconsin Department of Natural Resources
Madison, Wisconsin
1982

Cover: Bluegill fry 4 days after hatching. Note how well the eye has developed.

ABSTRACT

Factors influencing bluegill year class strength were evaluated in 3 small, winterkill lakes in northern Wisconsin during 1971-76. Only bluegill were present during the 1st 4 years of the study while walleye and other warm water species were added in 2 of the lakes during 1975-76. The density of parent bluegill was doubled in the remaining lake and no other species added during this latter study segment.

When no other species were present, the most important single variables affecting year class strength were size of parent females and date of 1st fry dispersal from the nest, the latter indicating that spawning beginning after the 1st week in July resulted in a weak year class. Water temperatures below 21 C also had an important impact on year class strength by interrupting or postponing spawning and slowing development of eggs and fry although no correlation was found between June water temperatures and standing crop of fall fingerlings. Daily mortality was much higher during the 4-day period following fry dispersal from the nest than during other life history stages, suggesting that year class strength may be set at this time.

Doubling the number of parent bluegill did not increase the number of fingerlings present in the fall although fry production increased. Increased fry production was also apparent when walleye and other warm water species were stocked, but fingerling production was sharply decreased. Where walleye were present, predation was determined to be the primary factor in the decrease. Young bluegill were insignificant food items of the other warm water species. However, low level predation by yellow perch fingerlings may have had a significant impact on bluegill numbers in 1 study year although other, unknown, forms of competition are also thought to have been involved.

Reduction of bluegill numbers by pumping fry from the nest and by selective chemical treatment of the limnetic area of a lake are discussed.

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Wisconsin Department of Natural Resources
Box 7921
Madison, Wisconsin 53707
1982

CONTENTS

INTRODUCTION

Many states throughout the Midwest have given a high priority to research dealing with slow growth and overcrowding in bluegill populations. Swingle (1950 and 1956) and Anderson (1973) provided the tools and criteria for determining balanced bluegill populations, but little is known about the factors that regulate recruitment of young fish into these populations. Both Beard (1971) and Hunter (1975) concluded that larvae survival appears to be a key to controlling the fate of fish populations. The present research was designed to determine some of the factors that influence bluegill year class strength and the time at which year class strength is set.

Three small, winterkill lakes (Camp, Lamereau, and Nancy) located in the Chequamegon National Forest in Bayfield County, Wisconsin, were selected for study during 1971-76. The 1st segment of the study dealt with determining bluegill reproductive success and identifying factors contributing to year class strength when no other fish species were present. The 2nd segment focused on determining the effects of interspecific and intraspecific relationships on the survival of young-of-the-year bluegill.

The fish populations in a number of northern Wisconsin lakes have changed in recent years from ones with desirable size bluegill and walleyes to populations dominated by small walleyes and a few large bluegill. Thus, during the 2nd study segment, 1 lake was set aside to study the relationship between walleyes and bluegill young of the year. During this same period, the effects of increased stocking of adult bluegill and the stocking of other warm water fish species were studied in the remaining 2 lakes.

DESCRIPTION OF STUDY AREA

Camp, Lamereau, and Nancy lakes are undeveloped seepage lakes with exceptionally clear water. All 3 lakes have very soft water with average total alkalinities ranging from 6 to 14 ppm and average pH ranging from 6.2 to 6.4 (Table 1). Nitrogen was highest in Nancy Lake because of the large amount of bottom organic material. Phosphorous was low in each lake.

Weekly air temperatures (based on a 7-day average of daily maximum and minimum temperatures) around the 3 lakes from 7 June through 1 August during the 6 study years averaged 18 C with ranges from 13 C to 23 C.* Average air temperatures for June and July varied little, from a low of 17 C to high of 19 C.

Camp Lake has a surface area of 4.0 ha and a maximum depth of 1.5 m. Bottom substrate is sand. During the study period approximately 20% of the lake had weed cover, primarily *Potamogeton amplifolius, Nuphar* spp., *Nymphaea* spp., *Juncus* spp., and *Typha* spp.

Lamereau Lake is a 4.2-ha lake with a maximum depth of 1.2 m. It has approximately 50% sand and 50% mud bottom, with aquatic macrophytes covering 30% of the lake during the study years. Dominant vegetation was *Potamogeton* spp., *Ceratophyllum demersum, Nuphar* spp., *Nymphaea* spp., and *Sparganium* spp.

Nancy Lake has a surface area of 2.7 ha, a maximum depth of 1.2 m, and a bottom substrate composed of 75% mud and 25% sand. Aquatic macrophytes covered 60% of the lake. Major species were *Potamogeton* spp., *Ceratophyllum demersum,* and *Nuphar* spp.

The 3 lakes were closed to fishing from 1972 through 1976 and, to my knowledge, no illegal fishing occurred during this time. Fishing was permitted during the 1st study year, but pressure appeared to be low or nonexistent due to the lakes' remote locations and previous lack of a fishery.

TABLE 1. *Water analysis of Camp, Lamereau, and Nancy lakes taken at 2-week intervals from May through September, 1971-76.*

	Camp		Lamereau		Nancy	
Parameters	Mean	Range	Mean	Range	Mean	Range
pH	6.4	5.9-7.0	6.3	5.7-6.9	6.2	5.7-7.2
Total Alkalinity (ppm)	14	4-28	8	3-20	6	1-15
Total Nitrogen (ppm)	0.78	0.27-2.23	0.93	0.33-1.97	1.22	0.49-3.28
Total Phosphates (ppm)	0.02	0.01-0.14	0.03	0.01-0.18	0.04	0.01-0.23

*Measurements in this report are expressed in metric. For conversion to English, see Appendix Table 1.

PART I: SURVIVAL OF YOUNG-OF-THE-YEAR BLUEGILL IN SINGLE SPECIES LAKES

METHODS

Stocking Adult Bluegill

Adult bluegill were stocked in the study lakes each year during the last week in May through 1st week of June in 1971-74 at a rate of approximately 62 females and 62 males/ha. Stocked fish annually totalled approximately 260 of each sex in Lamereau Lake, 165 in Nancy Lake, and 250 in Camp Lake. An error was made in calculating the surface area of Camp Lake in 1971 and resulted in the stocking of an additional 80 fish of each sex that year.

Parent bluegill were taken from Reynard Lake, Bayfield County, in 1971 while Wolf and Loyhead lakes in Washburn County provided fish during the remainder of the study. The bluegill were transported by hatchery truck and released at the single access point on each lake. The 3 lakes were visually checked for 1 week after stocking to determine the number of fish lost from handling and transportation; this loss averaged 4.5%.

Female bluegill were identified by the presence of eggs, while males were sexed by coloration and length of the ear lobe. Fish were not used in the study if their sex was uncertain.

Average size of stocked bluegill ranged from 145 to 203 mm, with females generally averaging slightly smaller than males (Table 2). Age ranged from 3 to 9 years and averaged 5-6 years. Excluding the Camp Lake stocking in 1971, because of the miscalculation of surface area, the average total weight of adult fish stocked in the study lakes ranged from 7.2 to 18.5 kg/ha with a grand average of 8.3 kg/ha.

Estimating Survival of Adults

Petersen population estimates of parent stocks were made in mid-July, mid-August, and mid-September from 1971 to 1974 in each lake. Fish were captured with fyke nets and marked by clipping different fin combinations. Recapture intervals were approximately 1 month and, except for the last estimate, coincided with the marking period for the next population estimate. Recaptures for the September estimate were made when the lakes were chemically treated in late September to early October.

Fecundity and Egg Analysis

At the time of stocking, ovaries were taken from 10 fish/25 mm length interval. Fecundity was determined by a gravimetric method. Three small sections of the ovary were taken and weighed on an analytical balance, after which the number of eggs in each section was counted. Eggs of all sizes were counted except for undeveloped, clear, transparent eggs near the inside ovary wall. The total number of eggs in the ovary was estimated by relating the average egg counts and weights of the sections to the total weight of the ovary. This method should yield an accurate estimate of egg production throughout the spawning season.

The fat content of a sample of bluegill eggs was measured as an indicator of quality. Sample ovaries were collected during the stocking period and frozen for storage. At the time of analysis, they were thawed, cleaned of any other body tissue, and weighed. Half of the ovary was removed, weighed, and oven-dried for 24 hours at approximately 100 C. Part of this dried material was weighed and processed in a goldfish fat extraction apparatus with anhydrous ether as a solvent (Savitz 1971). This procedure will extract most fatty material except the phospholipids and other polar fats, which are primarily located in cell membranes.

Observations of Spawning Activity

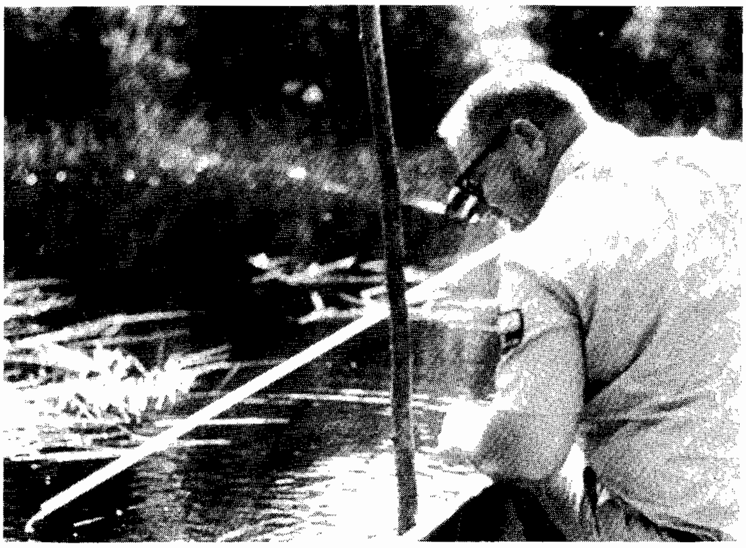
Daily observations of spawning activity were made from the time of stocking through July. The inshore area of the lakes was circuited with a canoe and data recorded on the initiation of spawning, length of time for nest building, nest location, time of egg deposition, and length of time for eggs to hatch and fry to develop and leave the nest.

The spawning season was defined as the entire period from the 1st observation of spawning activity until the last. A spawning period within the spawning season was defined as the period from nest building through fry dispersal. Nests built within 2 days of each other were considered as occurring in 1 spawning period. If new spawning began while fry were still on other nests, the new spawning was considered a separate spawning period.

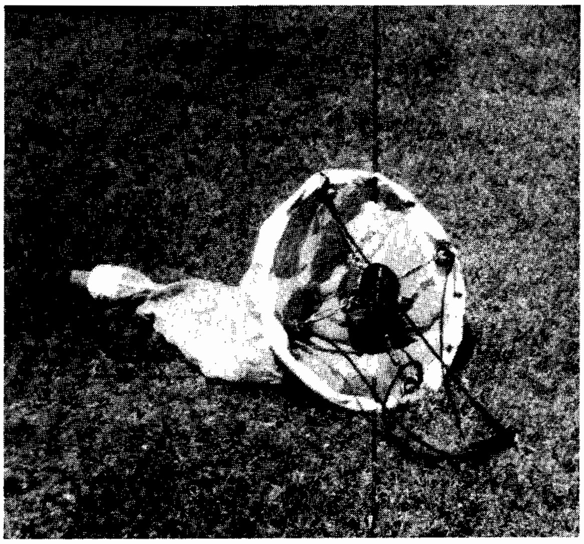
Taylor maximum and minimum water thermometers were placed on known spawning sites in about 0.5 m of water in each lake. Readings were recorded daily during spawning.

TABLE 2. *Number and average size of parent bluegill stocked in Camp, Lamereau, and Nancy lakes, 1971-74.*

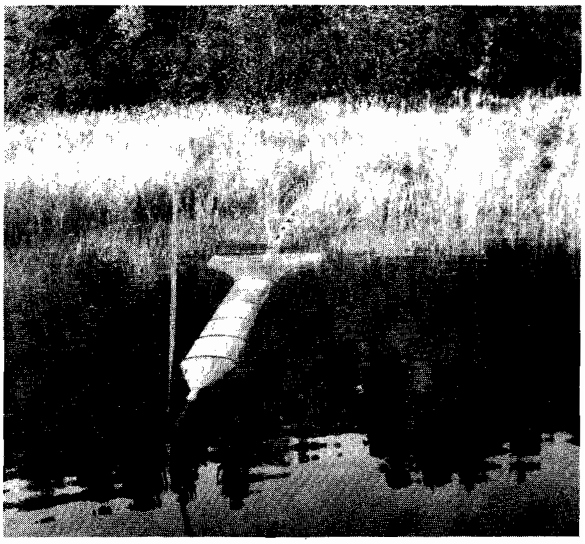
	Camp						Lamereau						Nancy					
	No. Fish Stocked		Average Length (mm)		Average Weight (g)		No. Fish Stocked		Average Length (mm)		Average Weight (g)		No. Fish Stocked		Average Length (mm)		Average Weight (g)	
Date	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
3 Jun 1971	330	332	203	201	159	154	263	260	193	201	140	147	165	164	196	203	146	157
24 May 1972	250	250	157	147	75	56	260	265	155	147	72	59	166	164	168	147	84	57
5 Jun 1973	249	249	145	145	69	59	261	259	157	145	81	62	163	165	160	147	83	63
7 Jun 1974	251	250	160	147	70	55	261	262	147	157	52	74	165	165	150	145	59	52



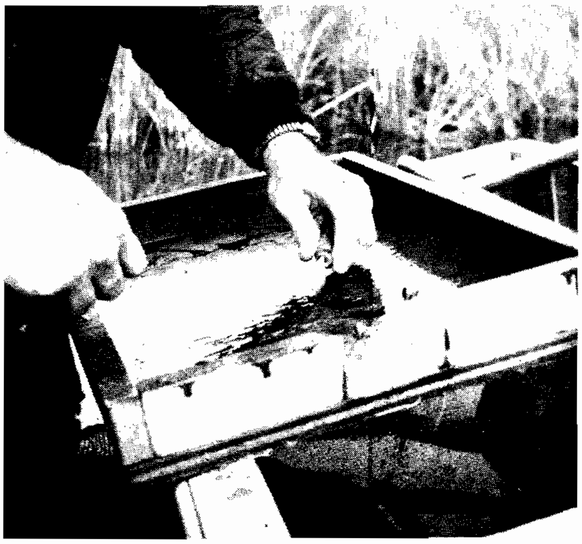
Plastic tube (1.2 m long and 12.7 mm in diameter) used to remove bluegill fry from the nest.



Tow net (0.5 m) used to collect bluegill fry from 1 to 4 days after dispersal from the nest.



Fyke net used to collect bluegill fingerlings each fall.



Fingerlings so caught were marked by squaring off the caudal fin, and were randomly released in the lake.

Following subsequent chemical treatment of the lake (shown here) fingerlings were collected and the ratio of marked to unmarked fish was used to estimate the fingerling population.

Miller high speed plankton sampler used to take biweekly zooplankton samples.

Estimating Hatching Success

Egg viability was estimated from samples suctioned from nests using a plastic tube (1.2 m length, 12.7 mm in diameter) and small dip net. The eggs were preserved in 10% formalin and 100 were examined under the microscope. The criteria of clear versus opaque was used to distinguish viable eggs from dead ones. Samples were taken daily until hatching was completed, with percent viability calculated independently for each sample.

The number of eggs hatching was estimated by multiplying the potential number of eggs deposited during the spawning season (based on fecundity analyses) by the average percent viability of eggs on the nest for all sampling dates in a given lake.

Population Estimates of Young-of-the-Year Bluegill

Fry were removed from 1 to 4 nests during each spawning period to estimate the number of fry/nest. Fry were removed by suction through a plastic tube 1.2 m long and 12.7 mm in diameter. Samples of fry were removed from the nest over a 20-minute period, which was adequate to remove over 99% of fry present. Fry were preserved in 10% formalin and the number/nest estimated volumetrically.

The number of fry dispersing during a spawning period was estimated by multiplying the average number of fry/nest by the total number of nests with fry. These summed gave the estimated number of fry dispersing over the entire spawning season.

The number of fry surviving 1-4 days after dispersal was estimated from captures made with a 0.5 m tow net (#00) equipped with a water volume meter. The net was mounted off the front of a boat and towed at a depth of 0.6 m. By knowing the volume of water sampled and the number of fry collected, a rough index of abundance was established.

Petersen population estimates were made to determine the number of fingerling bluegill present in late September through early October. The fingerlings were captured in small fyke nets (Beard and Priegel 1975) 0.3 m high and 0.9 m wide with 5 mm mesh netting. Fish were marked by cutting off the back edge of the caudal fin and were randomly released in the lakes. The lakes were then chemically treated with Fintrol-5 at a rate of 3 ppb. The population estimate was based on the ratio of marked to unmarked fish randomly picked up after treatment.

Movement and Growth Determinations

During the 1st 2 years of the study, 2 transects were established in the littoral area and 1 in the limnetic area of each lake to determine fry and fingerling migration. After the movement pattern had been established, 1 sample around the complete shore and through the middle of each lake was taken during the remainder of the study. Fish were collected with a 0.5 m tow net (#00) mounted off the front end of a boat and towed at a depth of 0.6 m.

Growth data were collected throughout the summer using fish collected in the 0.5-m net, minnow traps, and small fyke nets and fish picked up after chemical treatment each fall. A random subsample of 1,000 fish/month was measured to the nearest millimeter. If less than 1,000 fish were collected during a given month, all the fish were measured.

Analyses of Feeding Habits

Zooplankton samples were collected biweekly from June through mid-September using a Miller high speed plankton sampler with a number 20 mesh net. On each occasion, 2 samples were taken in Camp and Lamereau lakes, 1 from the open water area of each lake at the 0.6-m depth and the other from the weedy surface. In Nancy Lake only 1 sample was taken throughout the lake. Depth of the sample was 0.6 m. Samples were preserved in 5% formalin plus Lugol's solution for later identification.

Fry and fingerlings were collected for food habits analysis with the gear and in the manner described under the preceding heading. Fry samples (defined as fish 5-10 mm) were taken at least 4 days a week once the fry left the nest after each spawning period while fingerling bluegill (defined as fish 11 mm or larger) were collected biweekly from mid-July through mid-September.

Five fish were examined from each sample — a total of 1,269 fry and 852 fingerlings for the 3 lakes combined during the 1971-74 period. The entire digestive tract was removed, and the ingested food organisms were identified. Species identifications were made when possible, otherwise food organisms were identified to the smallest practical taxonomic group. Taxonomy and classification follow Ward and Whipple (1959), Pennak (1953), and Hilsenhoff (1975).

Measurements of food selectivity of bluegill fry were calculated using the electivity index described by Ivlev (1961), which is represented by the following equation:

$$E = \frac{r_i - P_i}{r_i + P_i}$$

where r_i is the relative quantity of any food item in the stomach as a percentage of the food consumed, and P_i is the relative quantity of the same food item in the environment expressed as a percentage of organisms sampled. Values of E may approach -1 to +1. An E value of zero is expected for a food item when no selective processes operate. Positive selection is indicated by E values between 0 and +1 and negative selection when E falls between 0 and -1.

TABLE 3. *Percent survival of adult bluegill in Camp, Lamereau, and Nancy lakes, 1971-74, beginning 1 week after stocking.*

	Survival Periods			
Lake and Year	Jun to Mid-Jul	Mid-Jul to Mid-Aug	Mid-Aug to Mid-Sep	All Season
Camp				
1971	59.1	74.4	85.5	37.6
1972	57.0	98.6	100.0*	56.2
1973	41.9	90.0	100.0*	37.7
1974	50.6	100.0*	98.2	49.7
Average	52.2	90.8	95.9	45.5
Lamereau				
1971	81.1	76.2	100.0*	61.8
1972	66.0	97.1	100.0*	64.1
1973	61.3	100.0*	97.6	59.8
1974	39.4	97.6	89.0	34.1
Average	61.9	92.7	96.6	55.4
Nancy				
1971	75.1	100.0*	100.0*	75.1
1972	72.7	100.0*	99.2	72.1
1973	89.9	90.4	87.5	71.1
1974	39.2	99.2	98.4	38.5
Average	69.3	97.4	96.3	65.0

*When the population estimate was higher than in the previous month, survival was considered to be 100.0%.

RESULTS AND DISCUSSION

Survival of Adult Bluegill

Survival of adult bluegill from 1 week after stocking to the end of the summer season 1971-74, averaged 45.5% in Camp Lake, 55.4% in Lamereau Lake, and 65.0% in Nancy Lake (Table 3). Fish lost to handling and transportation during the week following stocking averaged 4.5% for the 4 study years. Most mortality occurred during June through mid-July, with less than 10% spread over the remaining 2½ months.

The low survival from stocking until mid-July coincides with bluegill spawning, and survival for this period was probably linked to stress associated with spawning. It is also likely that some losses were due to predation by birds, snapping turtles, and other predators, but such losses should have been spread out over the summer and not predominantly highest during June and July.

Fecundity

TABLE 4. *Average number of eggs/female bluegill of various lengths stocked from Reynard, Wolf, and Loyhead lakes, 1971-74.*

Source of Females	Length (mm)	No. Ovaries Sampled	Avg. No. Eggs/Female*	Standard Deviation
Reynard Lake (1971)	152-175	12	10,900	± 2,500
	178-201	10	17,900	± 4,700
	203-226	7	23,500	± 7,100
Wolf and Loyhead Lakes (1972-74)	102-124	14	6,500	± 700
	127-150	45	8,900	± 900
	152-175	29	15,100	± 2,000
	178-201	13	21,000	± 4,500

*Based on gravimetric estimation from each ovary.

The number of eggs/female increased with fish size and varied from 6,500 to 23,500 (Table 4). Data from Wolf and Loyhead lakes were combined since separate egg counts for these waters showed similar results for fish of the same size. The average number of eggs/female in the present study averaged 4-34% lower than counts from the same size range of females from Buckeye Lake, Ohio (Morgan 1951*a*). The average fat content of bluegill eggs from 1971 through 1974 was 20.5%, 19.2%, 21.3%, and 19.7%, respectively. In 1971 and 1973 when the number of fingerlings was highest in all 3 lakes, the fat content was the highest. However, year-to-year differences in fat content were small and, because of the small sample sizes involved, no meaningful relationship to year class development could be determined.

Nikolskii (1969) concluded that the quality of the eggs, especially the amount of yolk and fat content, was important in the regulation of year class size.

Spawning Characteristics

Bluegills spawn in northern Wisconsin from late May to mid-August.

TABLE 5. *Length of the bluegill spawning season compared with the number of spawning periods in Camp, Lamereau, and Nancy lakes, 1971-74.*

Year	Camp		Lamereau		Nancy	
	Duration of Spawning Season (Days)	No. Spawning Periods	Duration of Spawning Season (Days)	No. Spawning Periods	Duration of Spawning Season (Days)	No. Spawning Periods
1971	37	4	50	6	31	4
1972	112	11	68	9	54	5
1973	54	7	52	7	59	7
1974	32	5	62	6	57	8

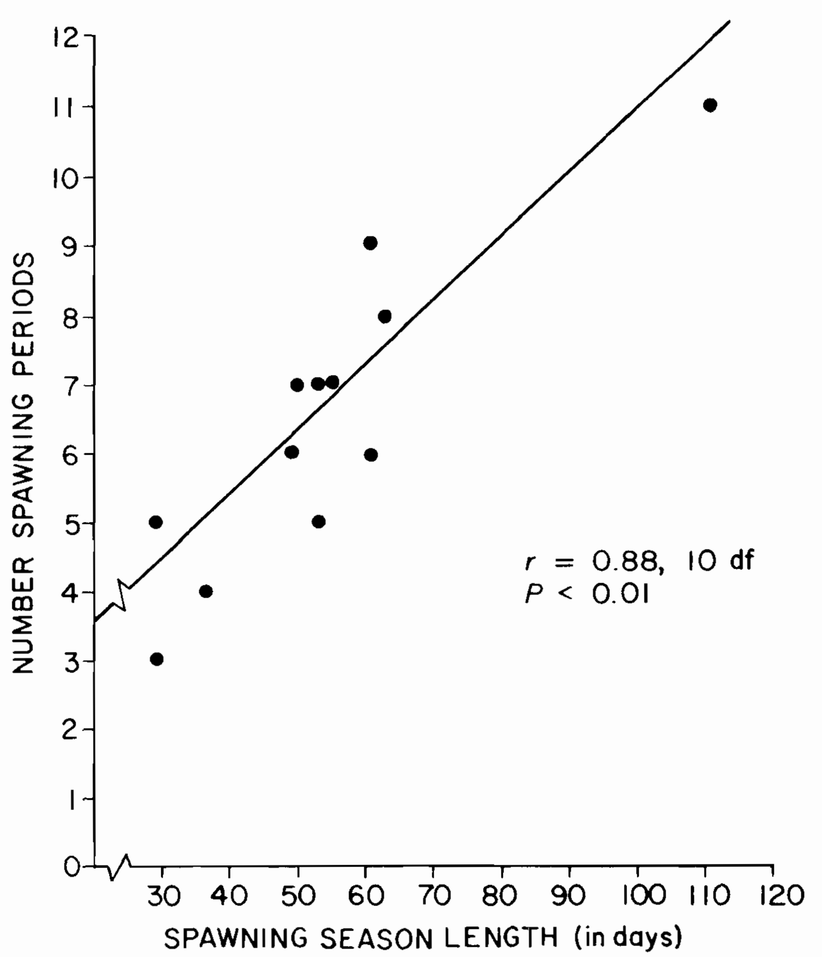


FIGURE 1. *Relationship between the length of the spawning season and the number of spawning periods in Camp, Lamereau, and Nancy Lakes, 1971-74.*

This time period is similar to that described by Morgan (1951*b*) for Buckeye Lake, Ohio. In general, spawning activity begins when the male moves into the shoreline area and makes a shallow depression by fanning the bottom with his tail, the size of the nest varying with the vigor of the male. The male then attracts the female to the nest and after a brief rousting interval, the female begins to lay her eggs. Eggs and milt are emitted with a quiver of the body as male and female sidle up to each other. After depositing her eggs the female moves off the nest, but the male remains on or near the nest, usually until the fry leave.

Spawning began in Camp, Lamereau, and Nancy lakes when the water temperature reached 21 C or above. Mraz and Cooper (1957) and Snow et al. (1962) also found that water temperatures approaching 21 C were needed for spawning to start. The length of the spawning season varied considerably from year to year, ranging from 31 to 112 days (Table 5). A significant relationship was found between the length of the spawning season and the number of individual spawning periods ($P < 0.01$) (Fig. 1). Thus, the longer the spawning season the greater the number of individual spawning periods.

Water temperature fluctuations provided a stimulus for repeated spawning in the study lakes and thus had an important influence on length of the spawning season (Fig. 2). At no time in any of the study lakes did spawning begin below 21 C or when the water temperature was dropping. Kramer and Smith (1960 and 1962) showed that sharp drops in water temperature followed by a rise were a stimulus for repeated largemouth bass spawning. A literature review on largemouth bass by Newburg (1975) cites a number of papers which discuss the role of water temperature fluctuations in multiple spawnings.

However, I found no significant statistical relationship between water temperature and duration of the spawning season. The relationship between cumulative degree days above 21 C from 10 June through July and the length of spawning season was not significant nor was the relationship between average weekly and monthly water temperatures during spawning and the length of the spawning season.

In any given year the effects of water temperature on spawning duration may be masked or influenced by a number of factors. For example, I observed that larger females spawned before smaller individuals when both were present in the same area. The number of eggs matured and deposited at any 1 spawning period could also regulate length of spawning. Swingle and Smith (1943) and Swingle (1956) suggested that length of the spawning season could be regulated by food supply and crowding. Although not a factor in the study lakes, predation by other fish species on eggs and fry could stimulate more spawning.

Spawning occurred on muck, sand, and gravel, which represented all bottom types in the lakes. There was a slight preference for bluegill in each lake to spawn on areas of gravel mixed with sticks. Bottom type was not considered to be a limiting factor in spawning because sufficient areas of all bottom types were available. Carbine (1939) found that bluegill did not thoroughly investigate all types of bottom for spawning, but that in Deep Lake, Michigan, they used whatever type was available. Survival and development of eggs and fry in our study lakes was similar on the different bottom substrates.

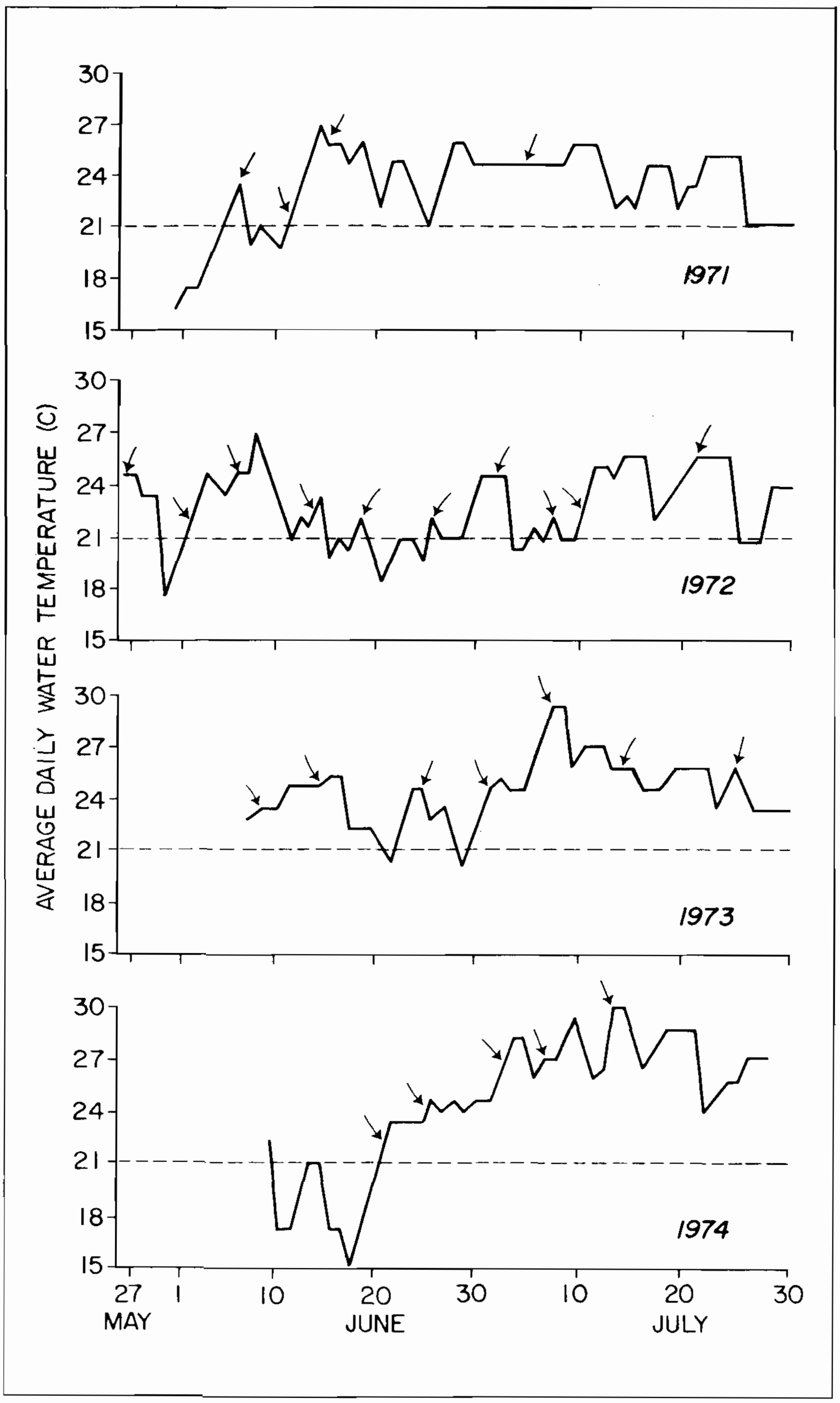


FIGURE 2. *Average daily water temperature in Camp Lake during bluegill spawning for each of 4 years, 1971-74. The arrows indicate start of individual spawning periods and the dashed lines indicate the water temperature at which bluegill began to spawn.*

Egg Deposition

The number of females stocked and the relationship between female length and fecundity were used to estimate the number of eggs laid by the females in the study lakes. In Camp and Nancy lakes the estimated number of eggs laid declined from 1971 through 1974 while in Lamereau Lake the number declined from 1971 through 1973 but increased in 1974 (Table 6). The estimated number of eggs was larger in 1971 because the average size of females stocked was approximately 51 mm longer than the average size of females stocked in the lakes during the next 3 summers.

Results from counts of fry on nests suggest that a female does not lay all of her eggs on 1 nest. From 1971 to 1974, nests with as many as 67,600 fry were found, and nests with 30,000 fry were quite common. Since the average fecundity of most of the larger parent fish was not over 24,000 eggs, more than 1 female must have been spawning on a nest. Visual observations of spawning activity also documented that a female deposited part of her eggs on 1 nest then moved to an adjacent nest and deposited more eggs. Ulrey et al. (1938) and Carbine (1939) found that more than 1 female bluegill laid eggs in a given nest.

Results from my study also suggest that bluegill are able to mature eggs at different rates within the ovary during the spawning season. All the females were ready to spawn in May at the time of stocking, yet spawning occurred over a period of 31-112 days. Toetz (1966) found that bluegill ova nearest the sinus were more mature than ova in the middle-medial and anterior-medial positions, and Chew (1974) found Florida largemouth bass ovaries to contain ova in all stages of development.

The fact that bluegill egg maturation initially occurs within a short period makes it plausible that eggs mature as the spawning season progresses. Samples of bluegill taken 1 May from Loyhead and Wolf Lakes showed little or no ovary development but ripe ovaries were developed by the end of May.

TABLE 6. *Estimated number of eggs laid (in 1,000's) by bluegill in Camp, Lamereau, and Nancy lakes, 1971-74.*

	Camp		Lamereau		Nancy	
Year	Total No.	No./ha	Total No.	No./ha	Total No.	No./ha
1971	6,660	1,660	5,020	1,190	3,340	1,240
1972	4,590	1,150	4,840	1,150	3,260	1,210
1973	3,160	790	3,410	810	2,250	840
1974	2,830	710	4,020	960	1,760	650

TABLE 7. *Percent viability of bluegill eggs on the nest during individual spawning periods in Camp, Lamereau, and Nancy lakes, 1971-74. Percents are averages of percentages determined for each day sampled within a spawning period, combining all 3 lakes.*

	Year				
Spawning Period	1971	1972	1973	1974	Average
I	54.8	38.2	70.1	48.4	51.9
II	94.1	59.3	82.6	76.3	79.3
III	96.7	76.8	89.2	—	90.3
IV	79.1	96.7	98.2	98.0	91.5
V	98.0*	97.6	99.5	99.0	98.4
VI	—	68.0	100.0*	79.5	77.2
VII	—	96.0*	—	75.0	80.2
VIII	—	97.0	—	95.0	96.0

*Only 1 egg sample taken during the spawning period.

Morgan (1951*b*) found that a buildup of the gonads in bluegill took place quickly in the spring between 20 April and 15 May. Swingle and Smith (1943) found that bluegill could mature eggs at intervals throughout the summer if sufficient food were available.

Egg Hatching

Water temperatures normally encountered during spawning in northern Wisconsin range from 19 to 26 C. In the study lakes, bluegill eggs hatched in 2-3 days at water temperatures above 21 C, but when water temperatures dropped below 21 C the hatching time was 4 days and in extreme cases 5 days. Mraz (1964) found that largemouth bass eggs hatch in 48 hours during temperature rises that continue into the mid-20's.

At no time during my study could water temperature be related to direct failure of the eggs to hatch. Larimore (1957) found that sudden drops in water temperature prompted the rapid growth of fungi infecting warmouth eggs. Water temperature could have an indirect effect on the eggs by slowing down development and making the eggs vulnerable to diseases over a longer period of time.

The percent viability of bluegill eggs on the nest from 1971 to 1974 averaged 86.5% the 1st day after deposition, and declined each day thereafter. On the 4th day after deposition eggs had an average viability of only 57.4%. Kramer and Smith (1962) found that survival of largemouth bass eggs in nests declined each day after spawning. Smith et al. (1958) determined that 98% of the largemouth bass eggs examined were viable, while Chew (1974) found that 95% of the Florida largemouth bass eggs examined were viable. Toetz (1966) demonstrated that 80-90% of the bluegill ova could be fertilized and hatched in the laboratory.

Percent viability of bluegill eggs varied with the individual spawning periods. The 1st 2 spawning periods, which usually occurred from the last week in May to mid-June, had the lowest and 3rd lowest average percent viability of eggs on the nest, respectively (Table 7). These percentages were based on an average of the percent viability determined for each day sampled in each lake for the 4 study years. The 3rd through 5th spawning periods had the highest percent of viable eggs on the nest, ranging from 76.8 to 99.5%. These spawning periods usually occurred from mid-June through the 1st week in July. Later spawning periods, when they occurred, showed intermediate to high levels of viable eggs.

There are 2 possible reasons for low egg viability during the 1st 2 spawning periods. It is possible that male sperm is not completely developed at this time so that all the eggs deposited by the females were not fertilized although normal mating occurred. Second, although no linear relationship between average daily water temperature and percent viability of eggs could be demonstrated, it is still possible that water temperature played an important role in the low viability of the eggs on the nest. Kramer and Smith (1962) found water temperature to be directly related to egg survival and nest success with largemouth bass.

Although it has been traditionally held that one of the important functions of the male while guarding the nest was to aerate the eggs, my observations suggest that this behavior has little effect on hatching success. In the study lakes from 1971 to 1974, when only adult bluegill were present, the male usually did not guard the nest after the eggs were laid. The few nests that were guarded during this time did not have higher hatching success than those nests abandoned after egg deposition. In 1975 and 1976 when other fish species were stocked in the study lakes along with bluegill, the majority of the males guarded the nest until the fry left. Thus, it is my opinion that guarding of the nest by the male bluegill is mostly to protect the eggs and fry from other fish species.

TABLE 8. *Date of 1st successful bluegill fry dispersal from the nest in Camp, Lamereau, and Nancy lakes, 1971-74.*

Year	Camp	Lamereau	Nancy
1971	14 Jun	16 Jun	22 Jun
1972	13 Jun	12 Jun	9 Jul
1973	18 Jun	10 Jul	18 Jun
1974	2 Jul	19 Jul	3 Jul

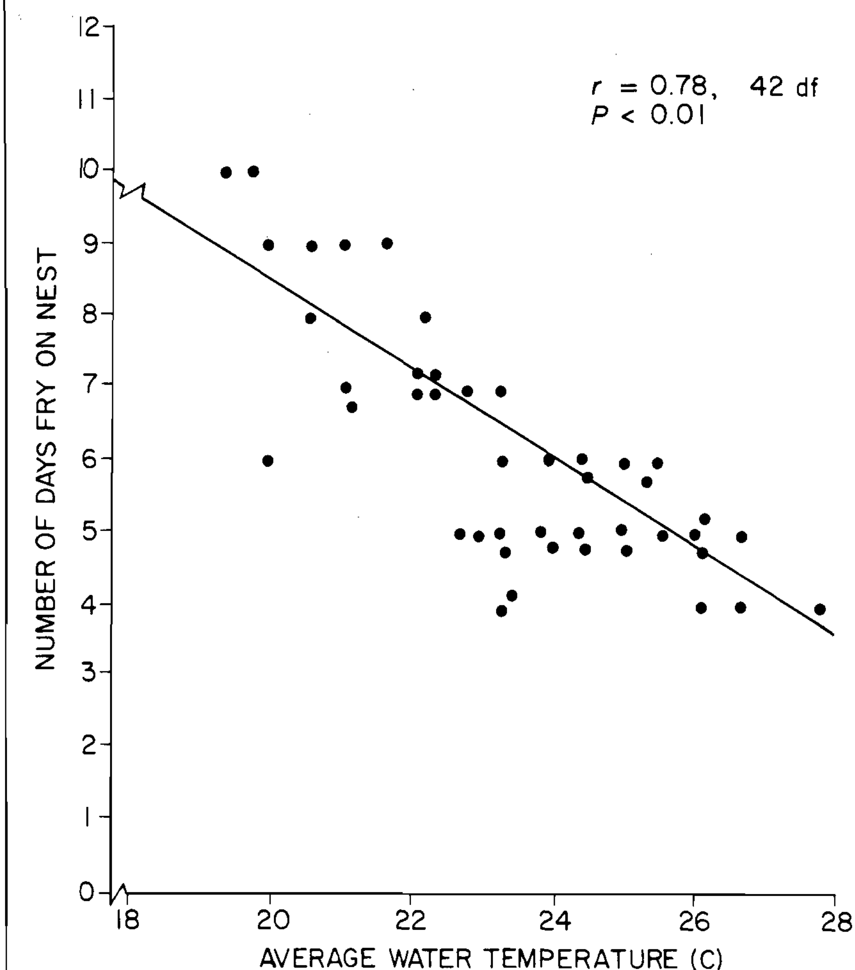


FIGURE 3. *Relationship between bluegill fry development on the nest and average water temperature.*

Movement

Water temperature showed a significant relationship ($P < 0.01$) to the length of time fry remained on the nest, which ranged from 4 to 10 days after hatching (Fig. 3). Although the relationship is presented as a linear regression, it is doubtful that any increase in water temperature beyond 27 C would decrease development time. Four days is probably a minimum amount of time for fry development on the nest.

Fry leave the nest when the yolk sac is almost absorbed and disperse over 1-3 days, depending on water temperature. The fry averaged 5 mm in length at this time. Time of 1st fry dispersal from the nest varied considerably in the 3 study lakes. The 1st fry left as early as 12 June and as late as 19 July (Table 8). As will be discussed in later sections, the earlier in the spawning season the fry disperse, the greater the food supply in the limnetic area of the study lakes and the longer the growing season for the bluegill. Fry that did not disperse from the nest until after mid-July were at a disadvantage because of the low food supply and shorter growing season.

Werner (1967 and 1969) and Faber (1967) demonstrated that young-of-the-year bluegill migrate from the littoral zone to the limnetic zone and back to the littoral. Bluegill in Camp, Lamereau, and Nancy lakes demonstrated this migrational pattern, even though the lakes did not have very well-defined littoral and limnetic regions.

Fry were collected in the limnetic area of the lake approximately 2 days after dispersal was complete. Since the bluegill were 15-20 mm at the time they returned to the littoral zone and their growth rate in the limnetic zone for the 1st 15 days in Camp and Lamereau lakes averaged 0.5 mm/day, I calculated that the bluegill remained in the limnetic zone for 30-40 days. This figure is supported by the facts that spawning usually started some time during the 1st 2 weeks of June and the earliest that bluegill were observed and collected in the littoral area was mid-July. Werner (1969) found that bluegill fry in Crane Lake, Indiana returned to the littoral area after reaching a size of 22-25 mm, which represented a stay in the limnetic zone of approximately 45 days.

I believe that the migrational behavior of the bluegill fry is an adaptation to move to an environment with fewer predators and a greater food supply. The littoral and limnetic areas can be distinguished ecologically by the number and kinds of predators and food organisms found in each. Aquatic insects of the families Belostomatidae, Corixidae, Aeschnidae, and Libellulidae were commonly found in the littoral region. Each of these has been implicated as a possible predator of fish larvae. Abundance of these insects in the limnetic area was much lower than in the littoral area. This differential abundance is probably more pronounced in the typical bluegill lake. In the limnetic water column, the young bluegill appeared transparent, which would make recognition by possible predators difficult. Also, in the limnetic zone, the number of desirable-sized zooplankton was greater than in the littoral zone. Ward and Whipple (1959) suggested that the limnetic zone of inland lakes has a zooplankton population large in number of individuals but not rich in species.

Production of Fry and Fingerlings

In Camp Lake, the number of active nests/spawning season varied from 52 to 127 over the 4 study years, while in Lamereau Lake the variation ranged from 16 to 134 (Table 9). In Nancy

TABLE 9. *The number of nests with bluegill fry, average number of fry per nest, potential number of fry dispersing from the nest, and estimated number of fry surviving 1-4 days after dispersal for Camp, Lamereau, and Nancy lakes, 1971-74.*

Lake and	No. Nests with Fry		Avg. No. Fry (in 1,000's)/Nest		Potential No. Fry (in 1000's) Leaving Nest		Estimated No. Fry (in 1,000's) Surviving 1-4 Days After Disposal	
Year	Total No.	No./Ha	Total No.	No./ha	Total No.	No./ha	Total No.	No./ha
Camp								
1971	122	30.5	21.9	5.5	2,580	645	*	
1972	127	31.8	15.6	3.9	2,080	520	671	168
1973	52	13.0	18.3	4.6	1,010	252	216	54
1974	77	19.3	31.8	8.0	2,420	605	818	205
Lamereau								
1971	134	31.9	21.6	5.1	2,790	664	*	
1972	88	21.0	10.3	2.5	1,010	242	503	120
1973	52	12.4	9.9	2.4	480	114	310	74
1974	16	3.8	0.3	—	5	1	*	
Nancy								
1971	30	11.1	18.4	6.8	546	202	*	
1972	31	11.5	8.1	3.0	244	90	*	
1973	81	30.0	5.7	2.1	634	235	*	
1974	29	10.7	1.2	0.4	44	16	*	

*No collections of fry were made at this life history stage.

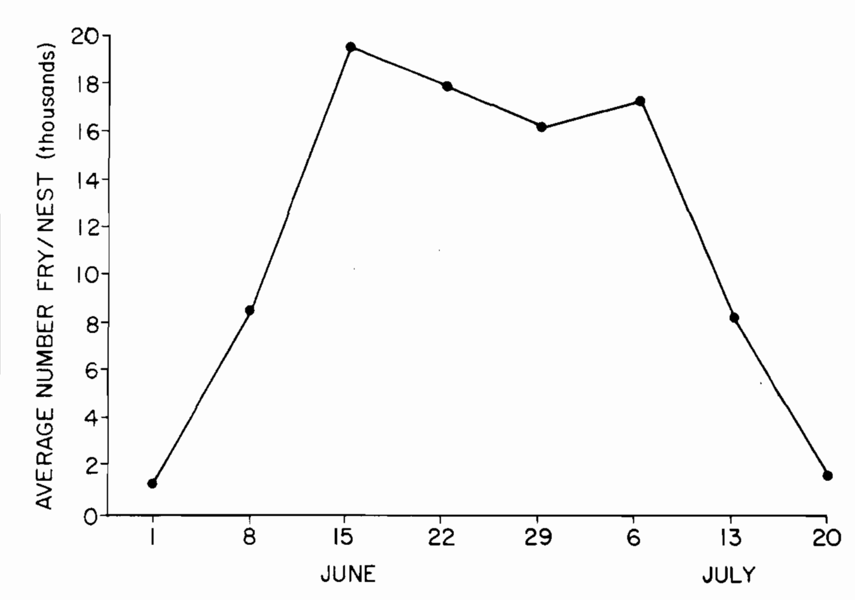


FIGURE 4. *The average number of bluegill fry/ nest during June and July, 1971-74. Dots indicate the average number of fry for 1-week periods beginning on the dates shown.*

Lake the number of active nests stayed fairly stable in 1971, 1972, and 1974 (29-31) but jumped to 81 in 1973. It should be noted that the total number of nests in a colony is not an indication of the number of nests with fry. For example, out of a colony of 20 nests, only 12 may have fry. Thus, only nests with fry were defined as active nests.

Considerable variation in the number of fry/nest occurred, ranging from below 100 to 67,600 fry/nest. In Camp Lake the average number of fry/ nest/spawning season ranged from 15,600 to 31,800, in Lamereau Lake from 300 to 21,600, and in Nancy Lake from 1,200 to 18,400.

The average number of fry/nest was the highest in all 3 study lakes from 15 June through 6 July (Fig. 4). At the start and end of the spawning season, the average number of fry/nest ranged from 1,000 to 8,500. Although bluegill develop eggs at different rates, the majority of the females became ripe over a 3-week period at the beginning of the spawning season, which accounts for the increased number of fry/nest during the 15 June - 6 July period. However, some spawning took place the 1st of June and some as late as mid-August.

Survival of fry on the nest was very high, with approximately 90-100% of the fry that hatched dispersing. In a few isolated cases, entire nests died, but this happened very few times, and no reason was apparent for this mortality. Kramer and Smith (1962) found very few dead largemouth bass fry on the nest except in cases where the entire nest failed.

Lower water temperatures have an indirect effect on fry survival on the nest by slowing development of the fry and increasing exposure time to diseases. I did not observe direct mortality of fry from declines in water temperature even though a few times water temperature reached 18 C for a 2-day period.

Estimated number of fry leaving the nests during the spawning season ranged from as many as 2,790,000 fry to as few as 5,000 for the 3 study lakes (Table 9). The number of fry present 4 days after dispersal was estimated dur-

TABLE 10. *Fall population estimates in number/ha and kg/ha of fingerling bluegill from Camp, Lamereau, and Nancy lakes, 1971-74.*

Lake and Year	No. Marked	No. Caught	No. Recaptures	Population Estimate: Total No. (in 1,000's)	Population Estimate: No./ha (in 1,000's)	Population Estimate: Kg/ha
Camp						
1971	10,000	52,674	350	1,500	376	124.1
1972	4,627	13,340	104	594	148	48.0
1973	7,618	13,742	350	299	75	60.2
1974	24,565	65,519	2,756	584	145	37.0
Lamereau						
1971	8,051	32,028	209	1,230	293	89.0
1972	4,025	6,416	110	235	56	39.6
1973	5,131	5,541	121	235	56	50.3
1974	8	114	1	< 1*	< 1	0.1
Nancy						
1971	12,253	22,570	978	283	105	106.7
1972	944	2,385	24	94	35	14.8
1973	13,638	15,338	510	410	152	80.8
1974	3,664	5,810	366	58	22	26.0

*Bailey's modification used for this estimate.

TABLE 11. *Daily and seasonal mortality rates for young-of-the-year bluegill in Camp and Lamereau lakes, 1971-74.*

Lake and Year	Daily Mortality*: Dispersal-Day 4	Daily Mortality*: Day 4 After Dispersal-Fall	Daily Mortality*: Dispersal-Fall	Seasonal Mortality** (Dispersal-Fall)
Camp				
1971	—	—	0.005	0.540
1972	0.283	0.001	0.012	1.251
1973	0.385	***	0.012	1.217
1974	0.271	0.003	0.014	1.423
Lamereau				
1971	—	—	0.008	0.821
1972	0.174	0.008	0.014	1.457
1973	0.109	0.003	0.007	0.713
1974	—	—	0.022	2.303

$*\ln \frac{N_2}{N_1} = -zt$

$**\ln \frac{N_2}{N_1} = -z.$

where N_1 = No. of bluegill at beginning of period; N_2 = No. of bluegill at end of period; z = total instantaneous mortality rate; and $t = 4$, 100, and 104 days, respectively.

***Population estimate at fall larger than at Day 4 after dispersal, indicating a theoretical daily mortality rate of 0.

—Population estimate not available for Day 4 after dispersal.

TABLE 12. *Average daily growth rate (mm) of bluegill fry during the 1st 2 weeks in the limnetic area of Camp, Lamereau, and Nancy lakes, 1974-76.*

Year	Camp	Lamereau	Nancy
1974	0.6	0.6	0.5
1975	0.5	0.5	0.7
1976	0.5	0.7	0.4

ing 1972-74 in Camp Lake and 1972-73 in Lamereau Lake. No estimates were made in Nancy Lake because of sampling difficulties in the limited space and dense aquatic vegetation. Fingerling production was estimated during 1971-74 in all 3 lakes. Estimates ranged from 54,000 to 205,000 fry/ha 4 days after dispersal (Table 9). End-of-summer population estimates of fingerlings ranged from a high of 376,000/ha (Camp Lake in 1971) to only a trace (Lamereau Lake in 1974) (Table 10). The latter was considered a year class failure. Unfortunately, the highest fingerling estimate was for a year (1971) in which earlier fry numbers are not available. The biomass of bluegill fingerlings ranged from 0.1-124.1 kg/ha and seemed to follow similar patterns, with 1971 showing the largest standing crop in each lake followed by 1973.

I calculated daily and seasonal mortality rates by comparing the number of bluegill present at dispersal, 4 days following dispersal, and at the end of summer (Table 11). Daily mortality was considerably higher during the 4 days following dispersal than during the 100 days from dispersal to fall. Also, the lowest seasonal mortality occurred in Lamereau Lake in 1973, when mortality rates were lowest during the 1st 4 days following dispersal. Thus, it appears that fry mortality during the first four days after dispersal has a great influence on year class strength.

Toetz (1966) defined the period between 6.4 and 9 days after fertilization as a critical period in the life history of the bluegill. In the present study, this would be the time when the fry were dispersing from the nest. Once the fry leave the nest, they change from an endogenous to exogenous source of energy.

Growth

Growth of bluegill fry during the 1st 14 days after dispersal from the nest was similar in all 3 lakes, ranging from 0.4 to 0.7 mm/day (Table 12). Werner (1969) found that limnetic bluegill fry grew at a rate of 0.4 mm/day in Crane Lake, Indiana. Krumholz (1949) determined that growth rates of bluegill fry from 12 to 25 mm total length were 0.1 mm/day in ponds where slow growth predominated and 0.6 mm/day in ponds conducive to faster growth. Lux (1960) determined that the daily increase in mean total length varied from 0.2 to 0.5mm/day for bluegill in the 11- to 39-mm size range.

No significant relationship could be established between growth rates of fry during the 1st 2 weeks in the limnetic zone and the date that fry dispersed from the nest.

The fastest growth generally occurred between July and August in all years, with growth slowing down by September (Table 13). The late spawning during 1974 in Lamereau and Nancy lakes contributed to the

TABLE 13. *Average total length (mm) at monthly intervals of young-of-the-year bluegill in Camp, Lamereau, and Nancy lakes, 1971-74.*

Lake and Year	Jun	Jul	Aug	Sep
Camp				
1971	6.8	12.8	30.7	31.8
1972	9.3	11.4	26.8	27.0
1973	7.5	10.8	35.2	37.4
1974	*	6.9	21.5	26.3
Lamereau				
1971	7.6	9.6	28.7	28.6
1972	8.7	8.7	26.9	32.6
1973	*	8.9	32.8	38.4
1974	*	7.6	20.0	41.0
Nancy				
1971	7.1	14.2	30.3	41.0
1972	8.7	7.3	25.5	28.5
1973	7.4	8.8	30.3	31.9
1974	*	7.6	22.3	42.4

*Spawning or fry dispersal did not take place until July.

Bluegill fry development on the nest from the 1st day after hatching to the day fry disperse from the nest. Day one is on the top, proceeding in order to day 8 (on the bottom) when fry disperse. Note the gradual loss of the yolk sac and the development of the eye.

larger growth increment in the 2 lakes between August and September, but the lower density of young bluegill in 1974 may also have been a factor. Latta and Merna (1976) found growth of age 0 bluegill to be density dependent. In the present study, however, the average length of fingerlings at the end of the summer and the number of fingerling/ha in each lake from 1971 to 1974 were not significantly related.

Figure 5 is a length frequency distribution of fingerling bluegill taken in late September and early October from Camp Lake. The distribution is similar to distributions from Lamereau and Nancy lakes during the same years. In 1971 and 1974 the final distribution of fingerlings was bimodal while in 1972 and 1973 the distribution was irregular. Mayhew (1976) found that in Lake Rathbun, Iowa, the length frequency distribution of age 0 bluegill was bimodal.

Feeding Habits

All 3 lakes exhibited a change in zooplankton abundance typical of temperate region lakes, with numbers decreasing from a high in June and July

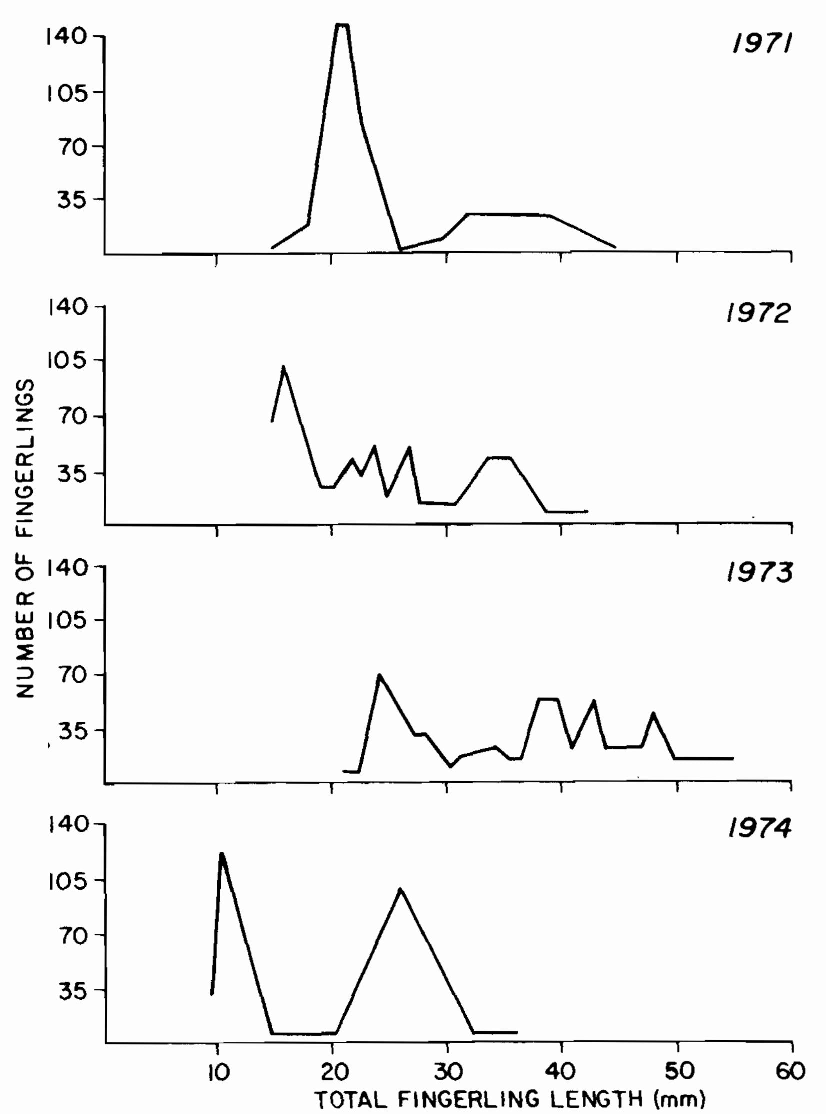


FIGURE 5. *Length frequency distribution of fingerling bluegill collected in Camp Lake for each of 4 years, 26 September-5 October, 1971-74.*

TABLE 14. *Percentage composition of zooplankton/liter found in Camp Lake during June-July and August-September, 1971-74.*

Species	1971 Jun-Jul	1971 Aug-Sep	1972 Jun-Jul	1972 Aug-Sep	1973 Jun-Jul	1973 Aug-Sep	1974 Jun-Jul	1974 Aug-Sep
Cladocera								
Daphnia spp.	37.8	40.0	23.0	—	16.3	—	26.0	—
Bosmina spp.	46.7	11.4	24.9	4.1	31.0	39.3	12.1	15.3
Chydorinae	0.3	2.9	0.1	4.1	0.3	1.5	0.4	2.7
Ceriodaphnia spp.	5.1	11.4	1.3	—	0.6	—	0.1	—
Holopedium gibberum	0.3	—	0.5	—	1.5	—	4.3	—
Diaphanosoma spp.	0.2	—	3.5	—	0.8	0.2	0.1	0.2
Polyphemus pediculus	—	—	4.2	—	11.5	—	9.0	—
Streblocerus serricaudatus	—	—	—	1.8	0.2	0.1	—	0.2
Sida crystallina	0.2	—	T	—	—	—	—	—
Leptodora kindtii	T	—	—	—	—	—	—	—
Copepoda								
Nauplius stage	*	*	27.7	85.4	24.6	57.1	31.6	76.9
Copepodid stage	*	*	8.1	0.4	7.1	1.5	6.4	0.9
Adult stage	9.4	34.3	5.6	4.1	6.1	0.3	9.9	3.8

*Counted adults only.
T = less than 0.05%.

to a low in August and September (Fig. 6). The highest number of zooplankton/liter was 140 in Camp Lake (1971) and 190 in Lamereau and Nancy (1974). Zooplankton populations in each lake were very unstable and subject to extreme variations over short periods of time.

Cladocera were the most abundant zooplankton during June and July but were outnumbered by copepods during August and September of most years (Tables 14-16). In all the lakes *Daphnia* spp., *Bosmina* spp., and *Holopedium gibberum* were the most abundant cladocerans, with *Daphnia* and *Holopedium* generally dominating in June and July and *Bosmina* in August and September. Several other species of Cladocera were abundant in Nancy Lake during 1 of the study years but remained at a low level in other years. Copepods were identified by stage of development rather than species because I felt that size played a more important part in the feeding habits of the young-of-the-year bluegill. Nauplii were the most abundant copepod in all 3 study lakes during 1972-74. Only adult copepods were enumerated in 1971.

The digestive tracts of 1,269 bluegill fry (5-10 mm) were examined from the study lakes during 1971-74. Percent empty stomachs averaged 34.0 in Camp Lake, 31.4 in Lamereau, and 25.6 in Nancy. Cladocerans (primarily *Daphnia*, *Bosmina*, and unknowns) and copepod nauplii were the principal

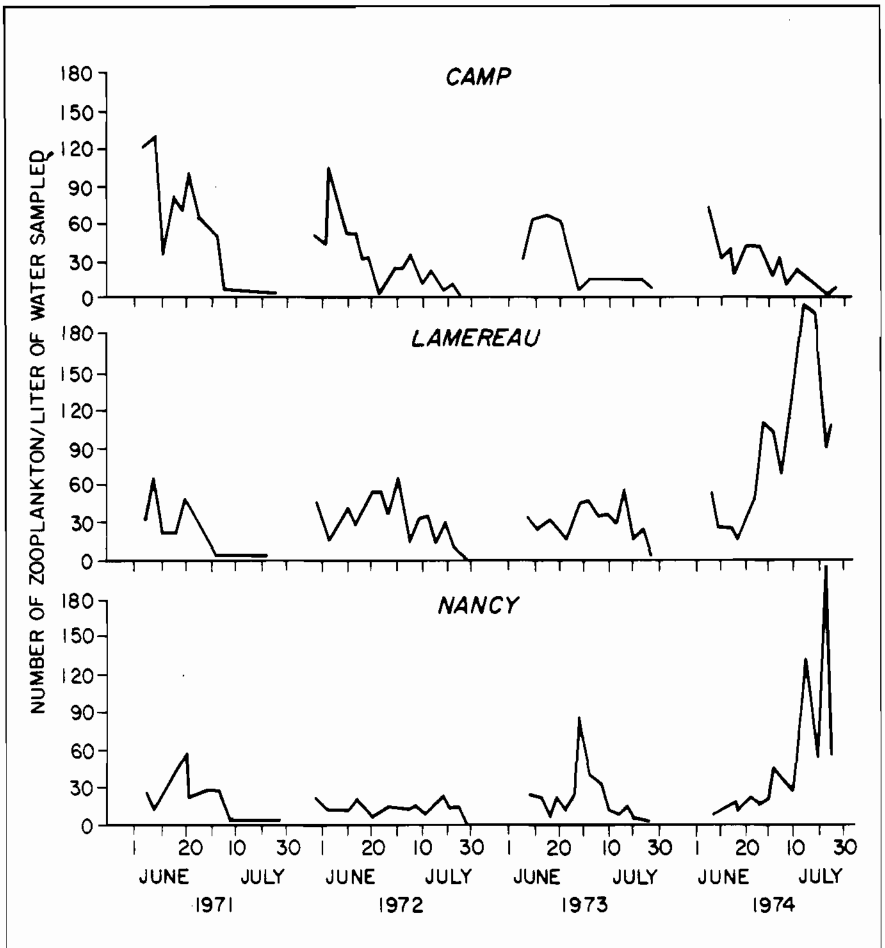


FIGURE 6. *Number of zooplankton/liter of water sampled during June and July, 1971-74, by lake. Numbers for August and September, not shown in this graph, were uniformly low.*

TABLE 15. *Percentage composition of zooplankton/liter found in Lamereau Lake during June-July and August-September, 1971-74.*

Species	1971 Jun-Jul	1971 Aug-Sep	1972 Jun-Jul	1972 Aug-Sep	1973 Jun-Jul	1973 Aug-Sep	1974 Jun-Jul	1974 Aug-Sep
Cladocera								
Daphnia spp.	76.7	34.2	47.0	—	41.0	3.6	47.3	50.7
Bosmina spp.	2.7	6.1	6.0	22.0	2.1	10.0	0.4	1.6
Chydorinae	T	—	0.2	—	0.5	7.4	T	0.1
Ceriodaphnia spp.	0.1	0.6	1.5	—	2.1	0.2	1.5	0.2
Holopedium gibberum	15.2	52.9	10.0	—	12.4	—	13.7	8.2
Diaphanosoma spp.	0.1	0.2	2.5	—	0.2	—	0.1	1.6
Polyphemus pediculus	1.7	0.8	6.8	—	5.1	—	3.4	3.7
Streblocerus serricaudatus	—	—	0.1	—	0.1	1.6	T	—
Sida crystallina	0.1	0.2	—	—	T	—	—	—
Leptodora kindtii	0.1	—	—	—	—	—	—	—
Ophryoxus gracilis	—	—	—	—	T	0.3	—	—
Ilocryptus spinifer	—	—	—	—	—	0.3	—	—
Acantholeberis curvirostris	—	—	—	—	T	—	—	—
Copepoda								
Nauplius stage	*	*	11.9	49.5	13.8	58.4	14.0	14.3
Copepodid stage	*	*	8.9	3.7	8.5	5.0	10.5	1.9
Adult stage	3.3	5.0	5.1	24.8	4.1	13.3	9.0	17.7

*Counted adults only.
T = less than 0.05%.

TABLE 16. *Percentage total composition of zooplankton/liter found in Nancy Lake during June-July and August-September, 1971-74.*

Species	1971 Jun-Jul	1971 Aug-Sep	1972 Jun-Jul	1972 Aug-Sep	1973 Jun-Jul	1973 Aug-Sep	1974 Jun-Jul	1974 Aug-Sep
Cladocera								
Daphnia spp.	43.7	2.3	25.5	3.2	25.3	1.0	31.1	42.7
Bosmina spp.	1.3	37.2	1.2	23.9	0.7	1.6	15.8	4.7
Chydorinae	—	—	2.0	3.2	0.3	14.6	0.2	1.6
Ceriodaphnia spp.	0.7	37.2	0.5	0.4	0.3	—	0.7	0.3
Holopedium gibberum	38.9	4.6	19.1	18.6	40.6	—	28.6	0.1
Diaphanosoma spp.	0.6	—	1.2	—	2.6	—	6.3	0.2
Polyphemus pediculus	1.6	—	26.7	—	6.0	—	3.5	—
Streblocerus serricaudatus	—	—	—	0.8	0.2	29.2	T	0.3
Sida crystallina	—	7.0	0.5	0.6	—	—	—	—
Ophryoxus gracilis	—	—	—	—	—	—	—	0.1
Copepoda								
Nauplius stage	*	*	12.9	40.6	12.7	16.1	7.3	39.1
Copepodid stage	*	*	4.6	2.4	3.0	7.3	2.6	5.7
Adult stage	13.2	11.6	5.8	6.2	8.2	30.2	3.9	5.2

*Counted adults only.
T = less than 0.05%.

food items in all lakes (Table 17). The "unknown" category of cladocerans consisted of body fragments that could not be assigned to any particular genus. It is assumed that they represent all of the Cladocera listed in Table 17 except the Chydorinae, which were readily identified in fragmented form because of their hard carapace. *Keratella* were extremely abundant in Camp Lake and many of those found in stomachs of Camp Lake fry may have been consumed incidentally with other organisms.

Other authors have found similar results in studies of bluegill fry feeding habits. Werner (1969) found that 22.8% of the bluegill fry stomachs examined in Crane Lake, Indiana, were empty and that the major food items were *Daphnia galeata* and copepods. In the present study there was an absence of algal cells in the stomach, also documented in the Crane Lake study. Siefert (1972) demonstrated that bluegill fry initiated feeding at a length of 5.0-5.9 mm and the major diet at this stage was the rotifer *Polyarthra* spp. and copepod nauplii. As the fry reached 8 mm, *Bosmina coregoni* and *Bosmina longirostris* became important diet items.

Measurements of a subsample of food items showed that bluegill fry selected items under 0.5 mm in length. Toetz (1966) found that mouth gape limited the size of food organisms consumed when the fry 1st leave the nest. Mouth gape for fry 6 days old was 0.20 mm and increased to 0.27 mm by the 9th day.

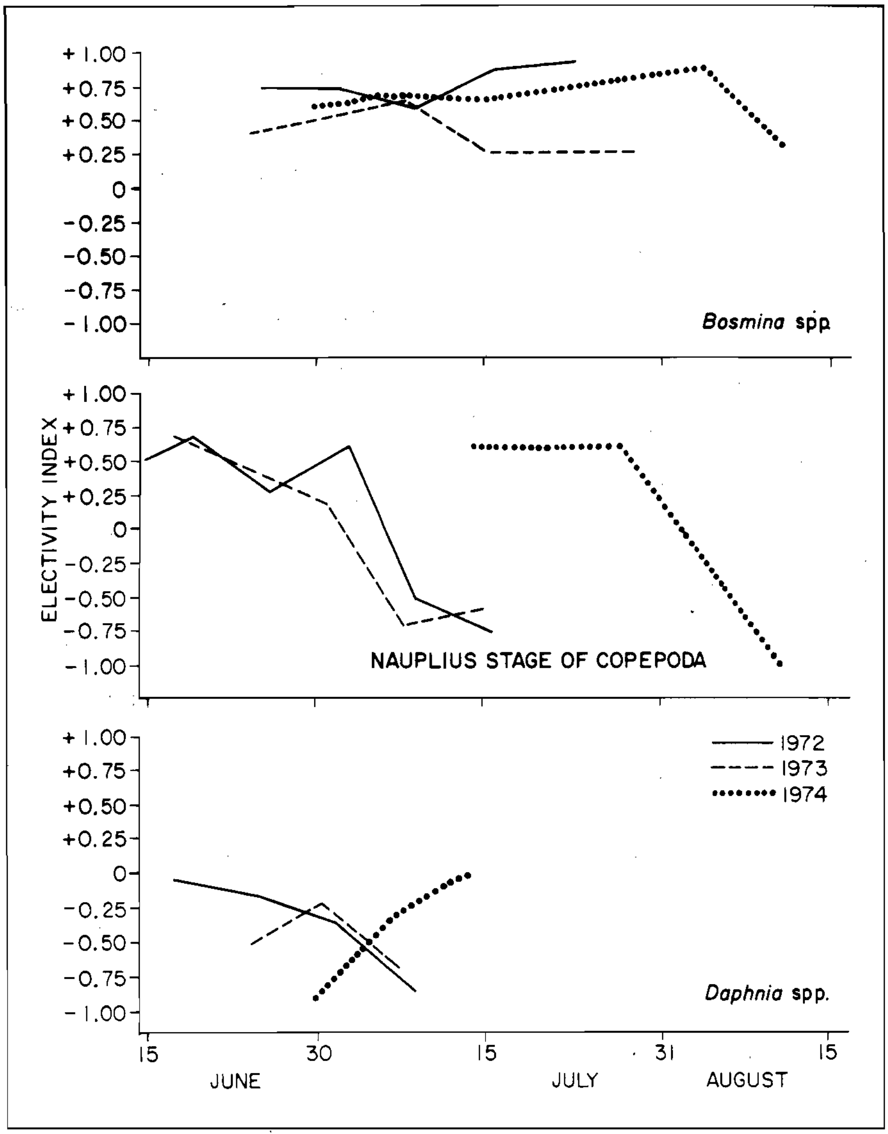


FIGURE 7. *Electivity indexes of bluegill 5-10 mm from Camp Lake, 1972-74, for 3 food items —* Bosmina *spp., nauplius stage of Copepoda, and* Daphnia *spp.*

Electivity indices were calculated for the dominant food items in Camp Lake during 1972-74 and in Nancy and Lamereau lakes during 1973-74. *Bosmina* spp. was a preferred food item in Camp Lake throughout the summer while copepod nauplii were preferred when the fry 1st left the nest but were avoided as they approached 8-10 mm in length (Fig. 7). *Daphnia* spp. was avoided throughout the summer.

Copepod nauplii and *Bosmina* spp. were positively selected in Nancy and Lamereau lakes throughout the summer, except in Nancy Lake during 1973, when *Bosmina* was negatively selected. *Daphnia* spp. was avoided in both lakes during most sampling periods. *Ceriodaphnia* spp., *Diaphanosoma* spp., and *Polyphemus pediculus* also showed positive selection in the 2 lakes during times of abundance.

This information on food selectivity agrees with that collected by Werner (1969) and Siefert (1972), who found that copepod nauplii and *Bosmina* spp. seem to be selected as food organisms and *Daphnia* spp. avoided when possible. Although all 3 organisms were dominant food items in my study, I felt that the size of the organisms more than species determined selectivity of feeding by bluegill fry. All the copepod nauplii collected were under 0.5-mm in length and 90% of the *Bosmina* spp. collected were under 0.5-mm.

Digestive tracts from 294 fingerlings 11 mm and larger were examined during 1971-74, and 99% were full.

Among fingerlings 11-19 mm, Cladocera (principally *Daphnia* spp., *Bosmina* spp., Chydorinae, and *Ceriodapnia* spp.) were the dominant food item in all 3 study lakes although copepods and insects were also consumed in good numbers (Tables 18-20).

When fingerlings reached 20 mm their feeding habits became more diverse with the cladoceran Chydorinae sharing dominance with adult copepods and insects, primarily Chironomids (Tables 18-20). Other Cladocera remained in the diet of these larger fingerling but at a reduced level.

I feel that the increased diet diversity of fingerlings 11-20 mm is due to the behavioral pattern of the bluegill. As stated previously, the fingerlings migrated from the limnetic region to the littoral region when they were 15-20 mm in length. Thus, available food items changed from limnetic organisms to littoral organisms, which were present in greater variety. The Chydorinae, aquatic insects, ostracods, and *Gammarus*, which accounted for much of the increase in diet diversity of bluegill 11-20 mm, all primarily inhabit the littoral region.

TABLE 17. *Stomach contents of bluegill fry from 5 to 10 mm in Camp, Lamereau, and Nancy lakes, 1971-74.*

Food Items	Camp (477 Stomachs-1,724 Items) Percentage of Stomachs with Food Items	Camp Percentage of Total Food Items in Stomachs	Lamereau (417 Stomachs-877 Items) Percentage of Stomachs with Food Items	Lamereau Percentage of Total Food Items in Stomachs	Nancy (375 Stomachs-842 Items) Percentage of Stomachs with Food Items	Nancy Percentage of Total Food Items in Stomachs
Rotatoria						
Monogonata						
Keratella spp.	9.2	8.1	2.3	0.6	1.1	0.7
Arthropoda						
Crustacea						
Branchiopoda						
Cladocera						
Daphnia spp.	13.2	7.4	20.2	20.3	6.2	2.5
Bosmina spp.	41.0	36.2	18.3	9.0	4.8	4.5
Chydorinae	7.5	1.6	3.2	5.2	1.1	0.5
Ceriodaphnia spp.	5.1	1.4	9.6	6.2	0.7	1.4
Polyphemus pediculus	1.4	0.8	1.4	0.8	2.2	1.1
Diaphanosoma spp.	1.0	0.4	0.5	0.1	4.0	1.7
Holopedium gibberum	—	—	0.5	0.5	0.4	0.1
Other Cladocera	34.9	25.9	52.3	48.0	38.1	55.9
Copepoda						
Nauplius stage	32.2	18.0	17.4	8.6	24.2	30.6
Copepodid stage	0.7	0.1	—	—	0.7	0.2
Malacostraca						
Gammarus spp.	—	—	0.5	0.1	—	—
Insecta						
Chironomidae	0.7	0.1	0.5	0.3	2.2	0.7
Other Insecta	—	—	0.9	0.2	—	—

TABLE 18. *Stomach contents of bluegill fingerlings 11 mm and over from Camp Lake, 1971-74.*

Food Items	Bluegill 11-19 mm (95 Stomachs-2, 186 Items) Percentage of Stomachs with Food Items	Bluegill 11-19 mm Percentage of Total Food Items in Stomachs	Bluegill 20 mm and over (227 Stomachs-5,429 Items) Percentage of Stomachs with Food Items	Bluegill 20 mm and over Percentage of Total Food Items in Stomachs
Mollusca				
Pelecypoda	—	—	0.4	T
Annelida				
Hirudinea	—	—	1.3	0.1
Arthropoda				
Crustacea				
Branchiopoda				
Conchostraca	—	—	0.4	T
Cladocera				
Chydorinae	13.7	3.4	82.3	56.1
Bosmina spp.	57.9	31.0	3.1	2.4
Daphnia spp.	63.2	33.3	—	—
Ceriodaphnia spp.	16.8	2.1	0.4	T
Holopedium gibberum	2.1	0.2	—	—
Polyphemus pediculus	12.6	3.7	—	—
Sida crystallina	—	—	2.2	0.2
Streblocerus serricaudatus	—	—	0.9	0.1
Other Cladocera	46.3	19.2	34.5	5.4
Ostracoda	—	—	21.2	3.5
Copepoda				
Nauplius stage	7.4	0.6	—	—
Copepodid stage	3.2	0.5	15.0	1.4
Adult stage	—	—	42.0	11.5
Malacostraca				
Gammarus spp.	—	—	19.0	1.9
Arachnida	—	—	2.2	0.1
Insecta				
Chironomidae	3.2	0.1	62.4	11.6
Other Insecta	25.3	5.9	46.9	5.5
Chordata				
Osteichthyes				
Bluegill	—	—	1.8	0.2

T = less than 0.05%

TABLE 19. *Stomach contents of bluegill fingerlings 11 mm and over from Lamereau lake, 1971-74.*

Food Items	Bluegill 11-19 mm (88 Stomachs-2,064 Items)		Bluegill 20 mm and over (147 Stomachs-5,888 Items)	
	Percentage of Stomachs with Food Items	Percentage of Total Food Items in Stomachs	Percentage of Stomachs with Food Items	Percentage of Total Food Items in Stomachs
Nematoda	—	—	0.7	T
Mollusca				
Pelecypoda	—	—	0.7	0.2
Arthropoda				
Crustacea				
Branchiopoda				
Cladocera				
Chydorinae	42.0	22.2	82.3	35.8
Bosmina spp.	35.2	8.9	12.2	3.3
Daphnia spp.	30.7	10.0	2.7	0.1
Ceriodaphnia spp.	25.0	6.8	6.8	0.3
Holopedium gibberum	—	—	0.7	T
Polyphemus pediculus	17.0	3.8	2.7	0.3
Sida crystallina	—	—	2.7	0.2
Streblocerus serricaudatus	4.5	1.5	1.3	0.1
Diaphanosoma spp.	5.7	0.8	2.7	0.2
Ophryoxus gracilis	—	—	1.4	0.1
Parophryoxus tubulatus	—	—	1.4	T
Other Cladocera	71.6	36.8	48.3	12.8
Ostracoda	5.7	0.3	23.8	2.0
Copepoda				
Nauplius stage	14.8	2.3	—	—
Copepodid stage	12.5	1.6	9.5	0.8
Adult stage	—	—	62.6	26.6
Malacostraca				
Gammarus spp.	2.3	0.3	1.4	0.1
Arachnida	2.3	0.1	6.1	0.3
Insecta				
Chironomidae	27.3	4.0	78.9	14.1
Other Insecta	8.0	0.5	36.0	2.6

T = less than 0.05%.

TABLE 20. *Stomach contents of bluegill fingerlings 11 mm and over from Nancy Lake, 1971-74.*

Food Items	Bluegill 11-19 mm (126 Stomachs-3,490 Items)		Bluegill 20 mm and over (168 Stomachs-9,966 Items)	
	Percentage of Stomachs with Food Items	Percentage of Total Food Items in Stomachs	Percentage of Stomachs with Food Items	Percentage of Total Food Items in Stomachs
Annelida				
Hirudinea	—	—	1.2	T
Arthropoda				
Crustacea				
Branchiopoda				
Cladocera				
Chydorinae	35.7	20.4	78.0	37.6
Bosmina spp.	35.7	6.1	11.3	2.7
Daphnia spp.	37.3	5.3	13.1	3.6
Ceriodaphnia spp.	27.0	7.7	14.3	2.9
Holopedium gibberum	3.2	0.1	0.6	T
Polyphemus pediculus	7.1	0.7	—	—
Sida crystallina	2.4	0.1	7.7	1.9
Streblocerus serricaudatus	0.8	0.3	3.6	0.2
Diaphanosoma spp.	7.9	0.6	1.8	T
Ophryoxus gracilis	—	—	0.6	T
Parophryoxus tubulatus	—	—	0.6	T
Other Cladocera	79.4	42.1	59.5	13.1
Ostracoda	—	—	20.8	0.9
Copepoda				
Nauplius stage	11.9	9.7	1.2	0.1
Copepodid stage	13.5	1.5	18.4	0.9
Adult stage	17.5	1.8	55.4	13.0
Arachnida	1.6	0.1	3.6	0.1
Insecta				
Chironomidae	31.0	3.3	85.1	16.2
Other Insecta	2.4	0.2	33.9	2.0

T = less than 0.05%.

PART II: VARIABLES CONTRIBUTING TO YEAR CLASS STRENGTH

METHODS

A simple linear correlation matrix was prepared to evaluate relationships among 10 variables associated with bluegill spawning and fingerling production. Variables measured are listed in Table 21 along with their units of measure and values. Values are rounded to 2-4 significant figures, which is ample for the analyses performed. The order of the variables moves from external or control variables associated with spawning and environmental conditions in the lakes during bluegill development (1st 5 variables) to variables directly involved in the fingerling production sequence from eggs to fall fingerlings (last 5 variables).

The 3 lakes and 4 years studied provided 12 trials. Since no replications could be made within these 12 combinations, only gross examination was possible for lake and year effects. However, 1-way and 2-way analysis of variance demonstrated the lack of statistically valid lake and year effects, likely because of the high variation and small sample sizes involved. The set of 12 trials was therefore examined as an independent set.

Values for the 10 variables analyzed generally show very poor statistical distributions, being nonsymmetrical or with excessive scatter. A simplified display of these as histograms is shown in the Appendix, Figure 1. Only 1 variable, fingerlings/ha, resembles a normal distribution. The poorest distribution is of the size of females stocked since large females from Reynard Lake were used in all lakes in 1971 and smaller fish from other sources were used in the other years. Thus, it is conceivable that female length correlations may simply be explained as an effect of 1971 or the differing source of the females.

Numerous combinations of multiple correlations were also tested. While many significant multiple correlations were found, none could be demonstrated to enhance the relationships found among the simple correlations and, in fact, many combinations degraded the probability level of the simple correlation through loss of degrees of freedom or reduction of the value of R. Thus, none are reported here.

RESULTS AND DISCUSSION

Results of the linear correlation matrix are provided in Figure 8. Correlation coefficient (R^2) values above 0.50 are reported with values significant at the 0.05 and 0.01 level indicated by asterisks. As always nonsignificant values do not necessarily indicate absence of a relationship between values, but a stronger case exists where significance levels are achieved.

No significant correlations existed among the 1st 5 variables. As these were identified as the "input" group, the lack of relationships suggests that they really are independent of each other as intended. The last 5 variables, which include the "production" associated measures, have numerous correlations, which confirms that the phases of production are related as expected. There is a rational sequence from eggs to fry to fingerlings with significant correlations between number of eggs hatching and number of nests with fry ($P < 0.05$); between number of nests with fry and number of fry dispersing ($P < 0.01$); and between number of fry dispersing and fingerling production in number ($P < 0.01$). Thus, these early production stages, which can be measured by methods described in Part I of this report, may give an indication of the direction that fall year class strength may take.

In terms of identifying factors associated with bluegill year class strength, the most interesting findings are seen when the 1st 5 variables (external or control variables) are matched against the last 5 (production variables). These relationships are discussed individually below.

$N = 12$
df = 10

	Size of adult females	Adult survival	June water temperature	First fry dispersal date	Preferred zooplankton	Eggs hatching	Nests with fry	Fry dispersal	Fingerlings in October (weight)
Adult survival									
June water temperature		0.51							
First fry dispersal date									
Preferred zooplankton									
Eggs hatching	0.80**			0.72**					
Nests with fry		0.52		0.76**		0.59*			
Fry dispersal				0.62*		0.68*	0.80**		
Fingerlings in October (weight)	0.76**	0.51		0.69*		0.90**	0.58*	0.57	
Fingerlings in October (No.)	0.69*			0.62*		0.84**	0.80**	0.87**	0.80**

*Significant at $P < 0.05$.
**Significant at $P < 0.01$.

FIGURE 8. *Linear correlation matrix for 10 variables associated with bluegill spawning and fingerling production in Camp, Lamereau, and Nancy lakes, 1971-74. Correlation coefficient (R^2) values below 0.50 were omitted.*

TABLE 21. *Variables used in the correlation analysis of factors related to bluegill year class strength, and their unit of measure and value for Camp, Lamereau, and Nancy lakes, 1971-74.*

		Camp Lake				Lamereau Lake				Nancy Lake			
Variable Analyzed	Unit	1971	1972	1973	1974	1971	1972	1973	1974	1971	1972	1973	1974
External Variables													
Size of adult females stocked*	mm	201	147	145	147	201	147	145	157	203	147	147	145
Adult survival to mid-July	%	59.1	57.0	41.9	50.6	81.1	66.0	61.3	39.4	75.1	72.7	89.9	39.2
Average June water temp.	C	21.1	20.6	21.7	19.4	23.3	21.7	21.7	21.1	20.0	20.6	23.3	20.6
Date of 1st fry dispersal	no. of days	165	165	169	183	167	164	191	200	173	191	169	184
Preferred June-July zooplankton	no./liter	19.6	7.4	9.0	2.9	12.7	15.8	15.2	12.2	2.4	1.9	2.7	3.5
Production Variables													
Eggs potentially hatching	no./ha (1,000's)	1,491	938	779	683	1,083	822	706	454	1,145	433	690	631
Nests with fry	no./ha	30.5	31.8	13.0	19.3	31.9	21.0	12.4	3.8	11.1	11.5	30.0	10.7
Potential fry dispersal	no./ha (1,000's)	645	520	252	605	664	242	114	1	202	90	235	16
Fingerlings in October	kg/ha	124.1	48.0	60.2	37.0	89.0	39.6	50.3	0.1	106.7	14.8	80.8	26.0
Fingerlings in October	no./ha	376.2	148.4	74.8	145.1	293.3	55.9	55.9	0.1	104.7	34.7	151.9	21.5

*Stocking rate was uniform for unit of surface acreage, except for Camp Lake in 1972 when 32% more fish were stocked due to an error in computing the lake's size.
**From 1 January, with adjustment made for leap year in 1972.

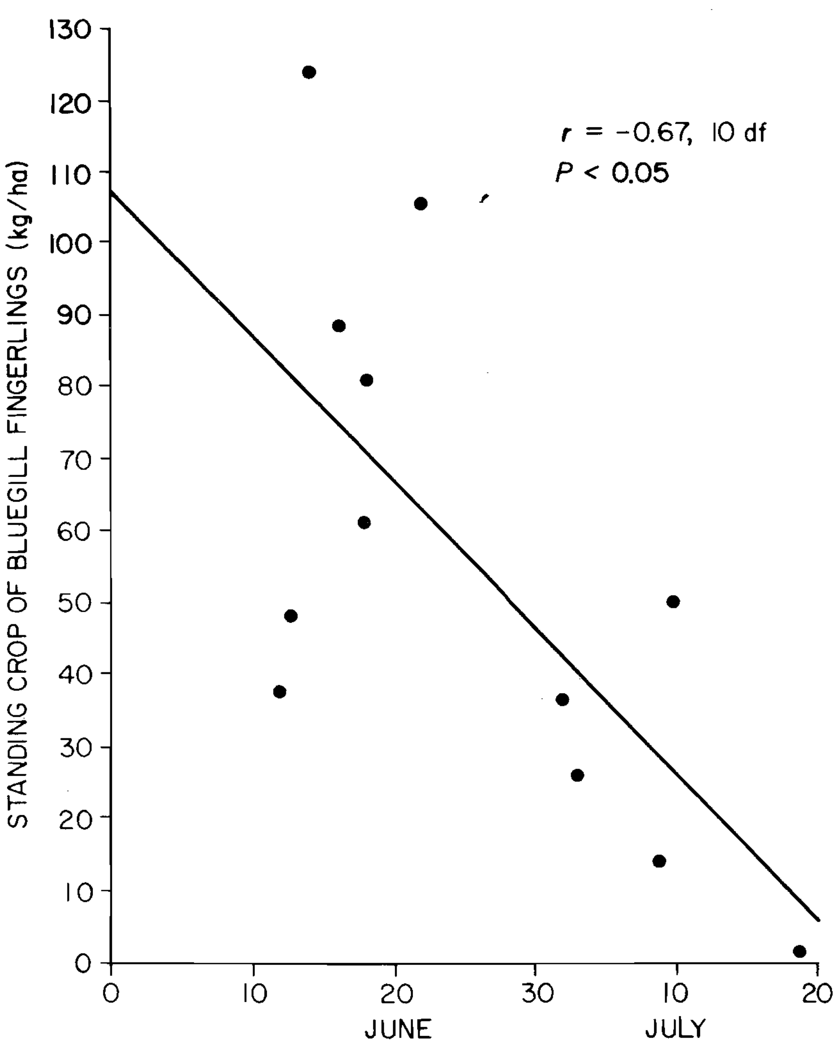


FIGURE 9. *Relationship between date of first fry dispersal and year class strength.*

Parent Stocks

The size of the adult females stocked in the study lakes had a significant effect upon the number of eggs hatching ($P < 0.01$) and standing crop of fall fingerlings in kg/ha ($P < 0.01$) and number/ha ($P < 0.05$). If this relationship holds in natural lakes and all other factors remain constant, one would expect the lakes with larger females to produce the largest year classes. However, caution is again urged in interpreting this relationship because of the unresolved effect of year of stocking and source of females.

Survival of adults was the lowest from stocking through mid-July. Although this time period coincided with peak spawning in the study lakes, the relationship between the survival of adults during spawning and the resulting year class was not significant.

Water Temperature

No significant relationship could be established between year class size and average monthly water temperatures in June. Schneider (1971) found that year class strength of panfish in Mills Lake, Michigan, was not correlated with monthly, seasonal, or annual temperature and Clady (1975), working with smallmouth bass in Katherine Lake, Michigan, could find no correlation between year class strength and summer temperatures during the 1st summer.

Even though I found no relationship between water temperature and year class strength during the 1st summer, I feel that the relationship must exist but was probably masked by other factors or by the water temperature data selected for analysis. When water temperatures remained below or fluctuated around 21 C, spawning was prolonged, and the later in the spawning season that a successful hatch occurred, the smaller the resulting year class. Also, water temperatures below 21 C slowed development of eggs and fry on the nest and made them vulnerable to diseases over a longer period. Water temperature must play an especially important role in northern Wisconsin where fluctuations above and below 21 C are quite common during spawning.

Fry Dispersal

One of the most interesting findings of this study was the significant positive relationship between date of 1st fry dispersal and all 5 variables relating to fingerling production: eggs potentially hatching, nests with fry, potential fry dispersal, and fall standing crop of fingerlings in weight (Fig. 9) and number. In particular, when spawning started after the 1st week in July, no matter how intense the effort, a weak year class resulted. I do not know whether this relationship holds only in the northern range of the bluegill where temperature fluctuations may prevent successful spawning until July or whether the same relationship would hold farther south where spawning begins in May.

Applying my finding that 1st spawnings after the 1st week in July resulted in a weak year class, I theorized that in lakes having spawning throughout the summer, only those occurring before the 1st week in July made significant contributions to the bluegill year class. If this is true, it appears that an entire year class was isolated in the limnetic area of the study lakes for a 2-week period after the 1st week in July. Counting from the date the earliest bluegill fry dispersed from the nest (12 June) and adding the 30-40 days spent in the limnetic area of the lake, I calculated that the young bluegill would return to the littoral area of the study lakes no earlier than 12 July. The exact date would vary from lake to lake and from year to year depending on the date of 1st fry dispersal and growth rate of fry in the limnetic zone, but in general, the entire year class of bluegill could be isolated in the limnetic region of northern Wisconsin lakes some time in July.

Feeding Habits

Feeding habits of the bluegill fry and fingerlings changed as their behavior patterns changed. When the fry 1st left the nest at 5 mm and migrated to the limnetic area of the study lakes, their food selection was limited to zooplankton 0.25 mm and under, which were predominantly copepod nauplii. As the fry reached 8-10 mm they were able to select organisms up to 0.5 mm in size, predominantly copepod nauplii, *Bosmina* spp., and early instar stages of *Daphnia* spp. From 11 to 15 mm, the fingerlings continued to feed on limnetic zooplankton but were able to feed on larger sizes of *Bosmina* spp. and *Daphnia* spp. as well as other species of limnetic zooplankton. Once the fry reached 15-20 mm and started to move back into the shoreline area of the study lakes, their diet became much more diverse and littoral organisms dominated. Chydorinae became very important in the diet at this stage as did chironomid larvae and adult copepods.

I feel that a critical survival period existed for bluegill fry at the time they 1st left the nest and changed from an endogenous to exogenous source of energy. If the right size and amounts of food were not available during the littoral to limnetic migration, the fry could starve. Correlations were calculated relating abundance of zooplankton preferred by the fry during June and July to year class strength in kilograms and number/ha of fall fingerlings. Neither calculation showed any significance even at $P < 0.50$. It is apparent that food was not a limiting factor in year class development during the study years.

PART III: INTRASPECIFIC AND INTERSPECIFIC RELATIONSHIPS

The emphasis of the final 2 years of the study (1975-76) was on survival of fry and fingerling bluegill with increased stocking density of adult bluegill and competition from other fish species. Nancy Lake was the study site for the effects of increased stocking rates, and Camp and Lamereau lakes were the sites chosen to study the effects of other fish species.

METHODS

Fish Stocking

Parent bluegill were stocked in Nancy Lake at a rate of 124 males and 124 females/ha (approximately 660 fish), a 2-fold increase from previous years. The parent fish were taken from Wolf and Loyhead lakes, Washburn County. The average size of female bluegill stocked in 1975 and 1976 was 135 and 140 mm respectively. These were the smallest females stocked in Nancy Lake in the 6-year study (Table 2).

Walleye fry were stocked in Camp Lake at 5,000/ha (20,000 fry), which is the rate recommended by the Department in its management guidelines for walleye. Parent bluegill were stocked at the same rate as they were from 1971 through 1974, approximately 62 males and 62 females/ha (500 fish).

Lamereau Lake was stocked with northern pike, largemouth bass, yellow perch, black crappie, and bluegill. Northern pike were stocked as fry at 2,471/ha (approximately 10,400 fish) and largemouth bass were stocked as 25- to 38-mm fingerlings at 247/ha (approximately 1,040 fish). Both stocking rates are commonly used by the Department in its management of the 2 species. Yellow perch and black crappie were stocked as adult spawners at approximately 62 males and 62 females/ha (520 fish of each species). The same number of adult bluegill were stocked in 1975 and 1976 as during the 1st 4 years of the study, and their average size was 145 mm, which was well within the range of parent fish stocked in 1971-74.

Feeding Habits of Predator Fish

Fish samples were collected from Nancy, Camp, and Lamereau lakes during July, August, and September to determine if young bluegill were being preyed upon. Twenty adult bluegill stomach samples were taken each sampling month in Nancy Lake, adult yellow perch and black crappie stomachs were taken at the rate of 10 each/month in Lamereau Lake, and up to 20 stomachs of walleye, northern pike, largemouth bass, yellow perch, and black crappie fingerlings were collected each month from Camp and Lamereau lakes. No adult bluegill were sampled in Camp and Lamereau lakes although the species was present in both lakes. The Nancy Lake sample was considered adequate to determine the species' feeding habits. Identification of food items, taxonomy, and classification is the same as that reported in Part I for bluegills.

Collection of Other Life History Data

Information on bluegill spawning behavior, adult survival, number and viability of eggs, number of fry/nest, number of fry dispersing, number of fry surviving 1-4 days after dispersal, and number of fingerling bluegill at the end of the summer was collected as previously described in Part I of this report. Petersen population estimates were made in the fall of 1975 and 1976 for the number of fingerling walleye, northern pike, largemouth bass, yellow perch, and black crappie. Petersen estimates were also made, at the same time that the adult bluegill population was estimated, to monitor survival of adult yellow perch and black crappie throughout the summer. Water temperature and zooplankton abundance were monitored using the methods described for 1971 through 1974.

RESULTS AND DISCUSSION

Intraspecific Relationships (Nancy Lake)

Survival of Adult Bluegill. Survival of adult spawners from stocking until mid-July was 72% in 1975 and 74% in 1976. These rates are comparable to those recorded during 1971-74 under the lower stocking rate (Table 3).

Production of Fry and Fingerlings. The number of nests with fry and potential number of fry leaving the nests were considerably higher in 1975-76 than in any previous year (Table 22). These increases can be attributed to the increased number of adult spawners. However, doubling the number of adult spawners in 1975 and 1976 did not produce a 2-fold increase in the number of fingerlings surviving until fall. Fingerling estimates for 1975-76 were within the range of values determined for the 4 previous study years.

Percent survival of bluegill fry from dispersal through the end of summer during 1975-76 was 26.2% and 18.8%, much lower than in the previous years. Latta and Merna (1976) found that survival of bluegill fry was a density dependent relationship, but no relationship between density and survival was evident at the 95% level in the present study.

Mraz and Cooper (1957) found that there was little apparent correlation

TABLE 22. *The number of nests with bluegill fry, average number of fry per nest, potential number of fry dispersing from the nest, and estimated number of fingerlings remaining in the fall in Nancy Lake under 2 stocking rates, 1971-76. All numbers are expressed in totals for Nancy Lake.*

Year	No. Parent Bluegill Stocked	No. Nests with Fry	Avg. No. Fry (in 1,000's) / Nest	Potential No. Fry (in 1000's) Leaving Nest	Petersen Population Est. of Fingerlings (in 1,000's)	95% Confidence Interval (in 1,000's)
1971	330	30	18.4	546	283	265-295
1972	330	31	8.1	244	94	60-130
1973	330	81	5.7	634	410	360-460
1974	330	29	1.2	44*	58	52-64
1975	660	128	11.4	1,290	336	315-355
1976	660	92	8.4	906	170	160-180

* Potential number of fry leaving the nest was less than the estimate of fingerlings remaining in the fall.

between the number of adult bluegill stocked in their ponds and size of the resulting year class. Newburg (1975) cited a number of references in his literature review on largemouth bass that found no relationship between the number of spawners and the number of fry produced.

Feeding Habits of Adult Bluegill. Predation by adult bluegill on their offspring had very little effect on year class development. Adult bluegill in Nancy Lake preferred Anisoptera and Chironomidae; the frequency of occurrence of bluegill fry and fingerlings in the stomachs of the adults was only 1.2% (Table 23). The abundant food supply in Nancy Lake may have allowed parent fish to choose the food they preferred. In a lake where food is limited and competition for it is intense, the adult bluegill might consume more fish than in Nancy Lake.

Interspecific Relationships (Camp Lake)

Survival and Growth of Stocked Fish. Survival of adult bluegill from June to mid-July averaged 51.8% during 1971-74 and 65.5% in 1975-76. Survival of walleye young-of-the-year from May through September in Camp Lake was 51% (10,200) in 1975 and 75% (15,000) in 1976. These survival rates are exceptional for walleye fry stocking and undoubtedly relate to the ideal combination of abundant food and no predators at the time of stocking. Total length of walleye fingerlings at the end of September averaged 106 mm (75-153 mm) in 1975 and 109 mm (76-162 mm) in 1976.

TABLE 23. *The percentage of adult black crappie, yellow perch, and bluegill stomachs containing various food items, Lamereau and Nancy lakes, 1975-76.*

Food Items	Lamereau		Nancy
	Black Crappie (120 Stomachs)	Yellow Perch (81 Stomachs)	Bluegill (121 Stomachs)
Mollusca			
Pelecypoda	2.0	—	14.0
Annelida			
Hirudinea	7.0	14.7	7.0
Arthropoda			
Crustacea			
Branchiopoda			
Cladocera	9.0	2.9	1.2
Copepoda	3.0	—	—
Malacostraca			
Gammarus spp.	41.0	2.9	—
Insecta			
Ephemeroptera	9.0	2.9	—
Odonata			
Anisoptera	57.0	47.0	51.2
Hemiptera	3.0	—	1.2
Trichoptera	7.0	2.9	2.3
Coleoptera	1.0	—	—
Diptera			
Chaoborus spp.	5.0	—	—
Chironomidae	30.0	8.8	30.2
Other Insecta	26.0	44.1	55.9
Chordata			
Osteichthyes			
Bluegill	5.0	—	1.2
Black crappie	2.0	—	*
Yellow perch	6.0	—	*
Other fish	11.0	8.8	*

* Food item not present in Nancy Lake.

Production of Fry and Fingerling Bluegill. The number of nests with bluegill fry and the potential number of fry leaving the nests were greater during 1975-76, increasing by as much as 2-3 times the number for the previous high year (Table 24). However, the number of fingerling bluegill surviving through September was only 1,000 in 1975 and 2,000 in 1976 compared to a previous low of 299,000 in 1973. It is quite possible that the presence of walleye in the lake stimulated the bluegill population to

TABLE 24. *The number of nests with bluegill fry, average number of fry/nest, potential number of fry dispersing from the nest, and estimated number of fingerlings remaining in the fall in Camp Lake before and after the introduction of walleye, 1971-76. All numbers are expressed in totals for Camp Lake.*

Year	No. Nests with Fry	Avg. No. Fry (in 1,000's) / Nest	Potential No. Fry (in 1,000's) Leaving Nest	Petersen Population Est. of Fingerlings (in 1,000's)	95% Confidence Interval (in 1,000's)
Before Introduction of Walleye					
1971	122	21.9	2,580	1,500	1,340-1,660
1972	127	15.6	2,080	594	530-660
1973	52	18.3	1,010	299	270-330
1974	77	31.8	2,420	584	575-590
After Introduction of Walleye					
1975	277	29.3	7,640	1	1-2
1976	271	31.0	8,070	2	2-2

TABLE 25. *Stomach contents of fingerling walleye from Camp Lake, 1975-76.*

	1975		1976	
	Walleye 31-118 mm (32 Stomachs-115 Items)		Walleye 42-129 mm (51 Stomachs-949 Items)	
Food Items	Percentage of Stomachs with Food Items	Percentage of Total Food Items in Stomachs	Percentage of Stomachs with Food Items	Percentage of Total Food Items in Stomachs
Arthropoda				
Crustacea				
Branchiopoda				
Cladocera				
Daphnia spp.	—	—	33.3	26.4
Sida crystallina	—	—	3.9	0.1
Other Cladocera	—	—	35.3	59.3
Copepoda	—	—	3.9	0.1
Malacostraca				
Gammarus spp.	37.5	33.0	41.2	7.5
Insecta				
Odonata				
Anisoptera	25.0	7.8	33.3	3.9
Trichoptera	3.1	0.9	—	—
Diptera				
Chironomidae	3.1	0.9	—	—
Other Insecta	6.2	1.7	7.8	0.4
Chordata				
Osteichthyes				
Bluegill	84.4	55.6	21.6	2.2

increase spawning and produced a 3-fold increase in the number of fry dispersing from the nest.

Feeding Habits of Fingerling Walleye. Bluegill were found in 84.4% of walleye stomachs in 1975 and 21.6% in 1976, comprising 55.6% and 2.2%, respectively, of the items eaten (Table 25). The lower consumption of bluegill in 1976 may be related to the higher survival of walleye fingerlings that year. The increased competition for the bluegill could have made them available to the walleyes over a shorter period of time and the random selection of stomachs over a 3-month period may not have reflected this change.

The frequency of occurrence of bluegill in walleye stomachs on a monthly basis from July through September in 1975 and 1976 suggests that there were very few bluegill remaining by the end of August. In 1975, bluegill occurred in 82.4% of the stomachs with contents in July and 92.8% in August, but no bluegill were found in walleye stomachs in September. In 1976, bluegill occurred in 58.3% of the walleye stomachs with contents in July and 16.0% in August, but, again, bluegill were absent from walleye stomachs in September. Thus, it appears that the walleyes had eaten most of the bluegill by the end of August and those few bluegill remaining may have been hard to find because of the available cover. Also, by September, most of the remaining bluegill were larger than could be consumed by walleyes.

Growth of the walleyes also reflects the low number of bluegill remaining after August. Growth was rapid through July and August, with walleyes averaging 97 mm at the end of August, but slowed considerably in September, when growth averaged only 11 mm. Morsell (1970) found that growth of young-of-the-year walleyes was greater when fish were the main food and decreased when invertebrates predominated in the diet. Preigel (1969) found that the greatest growth increase occurred in walleye fingerlings from July to August in Lake Winnebago when the walleyes reached 75 mm and switched to a fish diet.

The walleye fingerlings in Camp Lake changed to a diet of fish when they reached 60 mm, which occurred sometime during the 2nd or 3rd week in July. This is about the same time that the bluegill spawned in June would be moving into the littoral area of the lake. It is possible that the young bluegill were not readily available to the walleye before this time because of the transparency of bluegill in the limnetic area.

Walker and Applegate (1976), in studies conducted on South Dakota prairie potholes, found that fathead minnows began to appear in the diet of walleye fingerlings when they reached 62 mm in length. When walleyes became piscivorous, the abundance of fathead minnows decreased and they became relatively scarce by early August, at which time aquatic insects became walleyes' principal source of food. Houde (1967) found that walleyes in Oneida Lake fed almost exclusively on fish when they reached 50 mm. In Mille Lacs and Winnibigoshish lakes in Minnesota, walleye began feeding on fish at a size of 25-38 mm (Maloney and Johnson 1955).

Thus, it appears that fingerling walleye are predominantly fish predators, that young bluegill were their principal food in Camp Lake during July and August, and that this diet had a significant impact on bluegill numbers. Based on factors monitored from 1971 to 1976 which may be responsible for year class fluctuations in bluegill numbers, no event other than predation by walleyes occurred during 1975 and 1976 that could have caused the low survival of bluegill from fry dispersal until the end of the summer.

Interspecific Relationships (Lamereau Lake)

Survival and Growth of Stocked Fish. At end of the summer, the number of fingerling northern pike, largemouth bass, black crappie, and yellow perch varied considerably from 1975 to 1976. No northern pike were collected during the summer of 1975 although the fry seemed healthy when released. Survival at the end of summer 1976, was 296 (1.5%). Estimated number of largemouth bass fingerlings surviving during 1975 and 1976, respectively, were 24 (2.3%) and 58 (5.6%). Like the bluegill, adult black crappies and yellow perch were stocked before they spawned. Their survival was similar for the 2 study years, averaging 68.4% for bluegill, 71.3% for black crappie, and 66.2% for yellow perch. The survival of adult bluegill compares favorably with the previous 4-year average of 61.0%. Numbers of crappie and perch fingerlings present at the end of summer, 1975 and 1976, respectively, were 179 and 17,800 (black crappie) and 62,700 and 3,700 (yellow perch).

TABLE 26. *The number of nests with bluegill fry, average number of fry/nest, potential number of fry dispersing from the nest, and estimated number of fingerlings remaining in the fall in Lamereau Lake before and after the introduction of other species, 1971-76. All numbers are expressed in totals for Lamereau Lake.*

Year	No. Nests with Fry	Avg. No. Fry (in 1,000's) / Nest	Potential No. Fry (in 1,000's) Leaving Nest	Petersen Population Estimate of Fingerlings (in 1,000's)	95% Confidence Interval (in 1,000's)
Before Introduction of Other Species					
1971	134	21.6	2,790	1,230	1,040-1,360
1972	88	10.3	1,010	235	190-280
1973	52	9.9	480	235	195-275
1974	16	0.3	5	< 1	0-1
After Introduction of Other Species*					
1975	205	13.6	2,860	31	25-35
1976	158	12.4	2,090	55	50-60

*Northern pike, largemouth bass, yellow perch, and black crappie.

Seasonal growth of the largemouth bass, black crappie, yellow perch, and northern pike fingerlings varied inversely with the number of fish present within each species. Average length at the end of summer in 1975 and 1976, respectively, was 175 mm and 115 mm (largemouth bass); 67 mm and 54 mm (black crappie); 76 mm and 89 mm (yellow perch). Northern pike averaged 290 mm in the fall of 1976. Adult crappies reached 221 mm in 1975 and 236 mm in 1976, growing 28 mm and 18 mm in the respective years. Yellow perch adults averaged 229 mm in the fall of both years, showing a growth of 80 mm in 1975 and 77 mm in 1976. Growth rates of the fingerling yellow perch in Lamereau Lake in 1975 and 1976 were above average when compared with other northwestern Wisconsin lakes.

Production of Fry and Fingerling Bluegill. The number of bluegill nests with fry increased in 1975 and 1976 over previous years and the potential number of fry dispersing from the nest in 1975 was the highest of the 6-year study (Table 26). However, despite the high number of fry dispersing from the nest during 1975 and 1976, the percent survival from dispersal until October was the lowest of the study, 1.1% and 2.6%, respectively.

Feeding Habits of Fingerlings and Adults. Stomach samples of fingerling northern pike, largemouth bass, black crappie, and yellow perch and adult yellow perch and black crappie were taken to determine if predation by these species was responsible for the low survival of young bluegill. Except for yellow perch fingerlings, there was no conclusive evidence that predation by any one of the above species or all species combined had enough impact to account for the low survival during 1975 and 1976.

Northern pike fry did not survive the initial stocking in 1975 when survival of bluegill was the lowest and, although fish comprised the bulk of northern pike food in 1976, bluegill were found in only 3.4% of the stomachs (Table 27). Black crappie and perch fingerlings were the principal food and thus provided a "buffer" food supply, lessening predation on bluegill. Although the number of northern pike present in 1976 represented a good population for this species, the small number of bluegill found in their stomachs make it unlikely that predation by northern pike was responsible for the low bluegill survival. Studies conducted by McCarraher (1959), Gulish (1968), Beyerle (1971), and Rutledge and Prentice (1973) concluded that northern pike are not effective in reducing centrarchid numbers. However, none of these studies specifically dealt with young-of-the-year centrarchids.

The major diet of bass fingerlings consisted of Anisoptera larvae and Diptera larvae (Table 27). Bluegill were not identified in largemouth bass stomachs although black crappies and unknown fish remains occurred in relatively low frequency. Kramer and Smith (1960) and Stevenson (1971)

TABLE 27. *Stomach contents of fingerling largemouth bass and northern pike in Lamereau Lake, 1976.*

Food Items	Largemouth Bass (39 Stomachs-236 Items) Percentage of Stomachs with Food Items	Largemouth Bass Percentage of Total Food Items in Stomachs	Northern Pike (29 Stomachs-68 Items) Percentage of Stomachs with Food Items	Northern Pike Percentage of Total Food Items in Stomachs
Annelida				
Hirudinea	2.6	0.4	10.3	7.4
Arthropoda				
Crustacea				
Malacostraca				
Gammarus spp.	12.8	4.2	—	—
Insecta				
Ephemeroptera	2.6	0.4	3.4	1.5
Odonata				
Anisoptera	43.6	10.6	17.2	7.4
Hemiptera	7.7	2.5	—	—
Trichoptera	2.6	0.4	3.4	1.5
Diptera	28.2	76.3	—	—
Other Insecta	5.1	1.3	3.4	1.5
Chordata				
Osteichthyes				
Bluegill	—	—	3.4	1.5
Largemouth bass	—	—	3.4	1.5
Black crappie	5.1	0.8	48.3	52.9
Yellow perch	—	—	34.5	16.2
Other fish	17.9	3.0	17.2	8.8

TABLE 28. *Stomach contents of fingerling black crappie and yellow perch from Lamereau Lake, 1975-76.*

Food Items	Black Crappie (61 Stomachs-2,644 Items) Percentage of Stomachs with Food Items	Black Crappie Percentage of Total Food Items in Stomachs	Yellow Perch (30 Stomachs-462 Items) Percentage of Stomachs with Food Items	Yellow Perch Percentage of Total Food Items in Stomachs
Arthropoda				
Crustacea				
Branchiopoda				
Cladocera				
Chydorinae	54.1	4.7	10.0	0.9
Bosmina spp.	49.2	57.7	6.7	0.6
Daphnia spp.	3.3	0.1	20.0	50.9
Ceriodaphnia spp.	1.6	T	10.0	0.6
Diaphanosoma spp.	11.5	1.2	—	—
Polyphemus pediculus	1.6	0.9	3.3	2.2
Ophryoxus gracilis	—	—	6.7	0.6
Holopedium gibberum	—	—	3.3	1.1
Other Cladocera	41.0	11.4	50.0	37.2
Ostracoda	1.6	0.1	—	—
Copepoda	59.0	21.0	—	—
Insecta				
Ephemeroptera	3.3	0.3	—	—
Odonata				
Anisoptera	—	—	16.7	1.3
Diptera				
Chironomidae	42.6	1.7	20.0	1.5
Other Insecta	19.7	0.7	33.3	1.7
Chordata				
Osteichthyes				
Bluegill	3.3	0.1	6.7	1.3

T = less than 0.05%.

found that very few young-of-the-year largemouth bass had fish in their stomachs. McCammon et al. (1964), Keast and Webb (1966), Applegate and Mullan (1967), Newburg (1969), and Holland and Chambers (1971) found that largemouth bass feed on plankton and aquatic insects until they reach a size of 41-51 mm, when they switch to a fish diet.

Bluegill and unknown fish remains were found in a low percentage of the stomachs examined from black crappies and yellow perch fingerlings and adults, and contributed little to the percentage of fóod consumed (Tables 23 and 28). However, Chevalier's (1973) paper on cannibalism of walleye in Oneida Lake illustrated how a low occurence in stomachs can still lead to a substantial number of prey consumed. In an effort to explore this relationship, the following assumptions were formulated concerning yellow perch fingerlings in Lamereau Lake. Survival of yellow perch fingerlings over a 50-day period was 70% and perch ate only 1 bluegill/day with a 24-hour digestive rate. By multiplying the mean number of perch fingerlings surviving this 50-day period in 1975 (76,000) by frequency occurence of bluegill in the stomachs (6.7%), then expanding the result for 50 days, I calculated 255,000 bluegill were consumed during this period. In 1976, using the same assumptions, predation by yellow perch fingerlings was estimated to be only 15,000 during the 50-day period because of the low number of yellow perch fingerlings surviving that year.

Growth data indicated that bluegill were small enough to be eaten by yellow perch fingerlings in 1975 and 1976 but not by black crappie fingerlings. Data from adult black crappie and yellow perch, when expanded in the above manner were found to have very little impact on bluegill survival.

Thus, even though bluegill were found in only 6.7% of the yellow perch stomachs in 1975, predation by perch fingerlings could have had a significant impact on the survival of young-of-the-year bluegill. However, it is unlikely that predation by fingerling perch had much impact on bluegill survival in 1976. The unknown factors responsible for the low survival of young-of-the-year bluegill in 1976 may have also been operating in 1975, suggesting that predation by fingerling perch was not totally responsible for the low survival observed that year.

CONCLUSIONS

Year class strength of bluegill in the 3 study lakes was influenced by a number of factors, both abiotic and biotic. When no other species were present (1971-74), the most important single factors were size of parent females, and date of 1st fry dispersal from the nest.

Although water temperature data and standing crop of bluegill fingerlings did not show a significant statistical correlation, water temperature had an important impact on year class strength. Temperatures below 21 C postponed or interrupted spawning and slowed development of eggs and fry. The impact of 1st fry dispersal date on year class strength was particularly interesting. Spawning that began after the 1st week in July, no matter how intense, resulted in a weak year class.

Variables associated with fingerling production (potential eggs hatching, nests with fry, potential fry dispersing, and standing crop of fall fingerlings in weight and number) showed strong correlations, suggesting that the early stages of the bluegill production sequence might be used to predict fall year class strength.

The 4-day period following dispersal of fry from the nest showed a much higher daily mortality rate than other life history stages. While it may not be safe to state that year class strength is set at this time, this 4-day period certainly has a strong modifying influence on year class strength.

The impact of intraspecific competition on survival of young bluegill was studied in Nancy Lake during 1975-76 when twice as many adult spawners were stocked as in the previous 4 years. There was little correlation between the number of adult spawners stocked and the resulting year class. In both 1975 and 1976, greater numbers of fry dispersed from the nest than in previous years, but the estimated number of fall fingerlings was similar to previous years. No relationship between dispersal density and the resulting year class could be established.

Predation by adult bluegill in Nancy Lake had very little effect on fingerling abundance. This may have been due to the lake's abundant invertebrate population which provided an adequate food base. In lakes with limited food supply, intraspecific predation could assume a more important role.

The walleye fingerlings introduced into Camp Lake in 1975-76 were very effective predators on bluegill fingerlings. Even with a 3-fold increase in the number of bluegill fry leaving the nest, walleye predation reduced the bluegill numbers from dispersal to October by approximately 99.9%. This reduction was evident by the end of August. Fish were not found in the walleye stomachs during September of either year, and the condition of the walleyes deteriorated drastically from August to September.

During the 1975-76 study period in Lamereau Lake, survival of young bluegill was the lowest of the 6-year study, although fry dispersal from the nest was very high in both 1975 and 1976. Predation by northern pike and largemouth bass fingerlings, as well as predation by adult black crappies and yellow perch, had very little effect on bluegill year class development. Northern pike fed heavily on fish but black crappies and yellow perch fingerlings comprised the bulk of their diet. The few largemouth bass surviving through fall preferred aquatic insects rather than fish, and yellow perch adults fed more heavily on invertebrates than fish. Yellow perch and black crappie fingerlings also fed sparingly on young bluegill, but low-level predation by perch fingerlings may have had a significant impact on bluegill survival in 1975, though not in 1976, when fewer fingerling perch survived until fall. Growth data for 1975 and 1976 indicated that young bluegill were too large to be eaten by crappie fingerlings throughout most of the summer. Apparently, some species interactions other than predation affected year class development of bluegill after fry dispersal in Lamereau Lake in 1976 and may have contributed to its development in 1975.

MANAGEMENT IMPLICATIONS

The limited food base, low fishing pressure, and short growing season in many northern Wisconsin lakes make the reduction of bluegill year classes a desirable management strategy. Information derived from the present study on fry behavior and the relationship between 1st successful fry dispersal and year class strength leads to 2 possible methods of accomplishing this reduction.

A suggested method of eliminating a year class in small lakes (e.g., under 40 ha) would be to pump bluegill fry from the nest using a portable pump with a 38-mm hose. Although spawning extends from June through mid-August in northern Wisconsin, information from the present study suggests that any spawning that takes place after the 1st week in July, no matter how intense, will not add significantly to the year class. Thus, it would not be necessary for managers to pump beyond the 1st week in July.

The effort required by managers would be to determine when spawning 1st occurs and to traverse the shoreline to pick out the different spawning colonies. Nests with fry will appear white on the bottom, but if the presence of fry is uncertain a plastic tube can be used to check the nest. By becoming familiar with the location of nests in the 1st spawning period, one can readily determine when a new spawning period begins.

Although it might seem that a tremendous amount of time would be required to check the lake for new spawning, after nests from the 1st spawning period are pumped, checks every 5-7 days should allow the manager enough time to pick up any new spawning. This checking interval is based on the fact that the eggs are on the nest a minimum of 2 days before hatching and the fry are on the nest a minimum of 5 days before dispersal. Thus, for example, if eggs are deposited on Monday, the manager would have until the following Monday before the particular fry from this spawn would disperse.

In lakes larger than 40 ha, the pumping of nests would probably not be practical. Selective chemical treatment is a potential control technique in these larger lakes. The present study has demonstrated that the entire year class may be isolated in the limnetic area of a lake during a particular period. Assuming that bluegill fry feed on zooplankton and follow the same migrational patterns that zooplankton follow, the fry would not only be isolated in the limnetic area but may be isolated between the surface and approximately 4.6 m. A suitable toxicant could conceivably be applied at low enough concentrations to affect only the fry in this area. However, development of this technique for use needs further research. Bluegill would be the predominant species inhabiting the limnetic area in July in northern Wisconsin. By that time, black crappies would have migrated back into the littoral and walleyes would have left the limnetic area and become demersal around the shoreline.

From my experience and conversations with other research biologists in Wisconsin, the above techniques would have to be repeated 2 years in succession to effectively alter the size structure of a bluegill population.

Although walleyes were stocked as fry in Camp Lake and, as fingerlings, were very effective predators on bluegill young-of-the-year, it is doubtful that survival of walleye fry would be as high in lakes with established fish populations. Thus, managers might be better off stocking larger walleyes. Appropriate stocking densities should be experimentally determined.

Findings from my study also have application to walleye stocking in general. Walleyes stocked in the study lakes had a source of fish to feed upon once they reached 60 mm. By the end of August their condition factor was high, but during September, when very few bluegill were available, the condition factor was reduced significantly. The standard procedure in Wisconsin's walleye stocking program is to take the fry from the hatchery and stock them at a rate of 123,500-247,100/ha into ponds where they are raised to fingerling size before stocking into lakes. The walleyes are not provided fish in the hatchery ponds and must rely upon benthos and zooplankton as a food source. Given the high density of walleyes in these ponds, the food supply can be sharply reduced by the end of June. The low food base and high level of competition for the available food in July and August is likely to produce walleye in very poor condition for stocking. When introduced into a natural lake, survival seems questionable.

Two alternatives might be considered in stocking walleye. The 1st is to stock walleyes before they change to a fish diet sometime in June or early July. The 2nd is to provide a spawning population of fathead minnows, bluegill, or some other fish species in the hatchery ponds to provide the walleye a fish diet.

The average mortality and growth rates of adult bluegill monitored in my study may be helpful to fish managers involved with stocking reclaimed lakes or making recommendations for stocking farm ponds. In the absence of fish predation and angling, mortality averaged 47.4% (28.2-64.4%) from June through September, with 90% occurring by mid-July. Average growth during the summer was 38 mm (30-43 mm) and 0.10 kg (0.07-0.13 kg). The best single summer's growth occurred in Camp Lake where the average size increased from 157 to 206 mm with a weight increase from 0.08 to 0.23 kg. The only sure method of single sex stocking is to use only female bluegill that can be proven to be females by pressing eggs from the vent.

SUMMARY

(1) The study was conducted from 1971 to 1976 on 3 soft-water seepage lakes located in northern Wisconsin: Camp Lake, 4.0 ha, maximum depth 1.5 m; Lamereau Lake, 4.2 ha, maximum depth 1.2 m; and Nancy Lake, 2.7 ha, maximum depth 1.2 m.

(2) The study was divided into the following parts: Stocking known numbers of adult bluegill and following survival of their progeny while monitoring factors that may influence survival; examining the relationship between increased stocking densities of adult bluegill and the resulting young produced; and determining the effects of competition from other fish species on the survival of young-of-the-year bluegill.

(3) The average size of adult bluegill stocked ranged from 145 to 203 mm. Loss of fish from handling and transportation was low, averaging 4.5%. Survival of adults was lowest from stocking until mid-July, averaging 52.2% in Camp Lake and 61.9% and 69.3% in Lamereau and Nancy lakes, respectively. Survival of parent stock from mid-July through September in all 3 lakes averaged 95%.

(4) Spawning did not begin until water temperatures reached 21 C. Water temperature fluctuations were an important factor regulating the length of the spawning season by providing a stimulus for repeated spawning. The longer the spawning season, the greater the number of individual spawning periods ($P < 0.01$).

(5) The ability of bluegill to mature eggs at different rates within the ovary increases the possibility of at least 1 successful spawn during the summer. However, number of fry/nest was low for spawnings after the 1st week in July.

(6) Average viability for all sampling dates of bluegill eggs on nests from 1971 through 1974 in all 3 study lakes was 86.5%, with viability declining each day after deposition to an average of 57.4% by the 4th day. Eggs deposited in mid-June through the 1st week in July had the highest percent of viable eggs/nest.

(7) Bluegill fry in the study lakes demonstrated an intralacustrine migration pattern. At 5 mm, they left the nest and migrated to the limnetic area, remained there until they reached 15-20 mm, then migrated back to the littoral area. The growth rate of the fry in the limnetic area averaged 0.5 mm/day. Assuming a constant growth rate during this period, young bluegill remained in the limnetic area for 30-40 days.

(8) Survival of the fry on the nest was high with approximately 90-100% of the fry that hatched dispersing.

(9) Comparing 3 life history stages, daily mortality of young-of-the-year bluegill was much higher in Camp and Lamereau lakes from fry dispersal to the subsequent 4 days, than during the other 2 stages. Comparisons were not available for Nancy Lake. Thus, fry mortality during this period has a great influence on year class strength although I did not determine for certain when year class strength was established.

(10) Growth of age 0 bluegill was inversely related to density in the fall.

(11) The most important food items of fry from 5 to 10 mm were copepod nauplii, *Daphnia* spp., and *Bosmina* spp. Size of food available seemed to be a more important selection criterion than species.

(12) Bluegill fingerlings from 11 to 19 mm fed almost entirely on Cladocera. Once the fingerlings reached 20 mm and migrated back to the littoral area, their feeding habits became more diverse with Chydorinae, aquatic insects, ostracods and *Gammarus* spp. becoming more evident in the diet.

(13) Of the variables analyzed, size of the adult females stocked and date of 1st fry dispersal had the most influence on bluegill year class strength.

(14) Water temperature measurements and resulting standing crop of bluegill fingerlings did not show a significant correlation, but temperature played a very important role in determining year class strength through its influence on time of spawning and time required for egg hatching.

(15) Doubling the number of adult spawners in Nancy Lake produced considerably more fry dispersing from the nest, but the resulting year class was not any stronger than in previous years.

(16) With the introduction and high survival of walleye fry in Camp Lake in 1975 and 1976 and the utilization by fingerling walleye of bluegill as food, there was no doubt that walleye predation determined the year class strength of bluegill in both years.

(17) There was no evidence that predation by fingerling northern pike, largemouth bass, and black crappie, and adult yellow perch and black crappie had enough impact on the bluegill young-of-the-year in Lamereau Lake to account for their low survival during 1975 and 1976. Low-level predation by yellow perch fingerlings may have had a significant impact on bluegill survival in 1975.

(18) Bluegill numbers may be reduced in small lakes by removing fry from nests with a pump. Information from the present study suggests that any spawning occurring after the 1st week in July, no matter how intense, will not add appreciably to the year class. Thus, managers should concentrate on the early spawning periods.

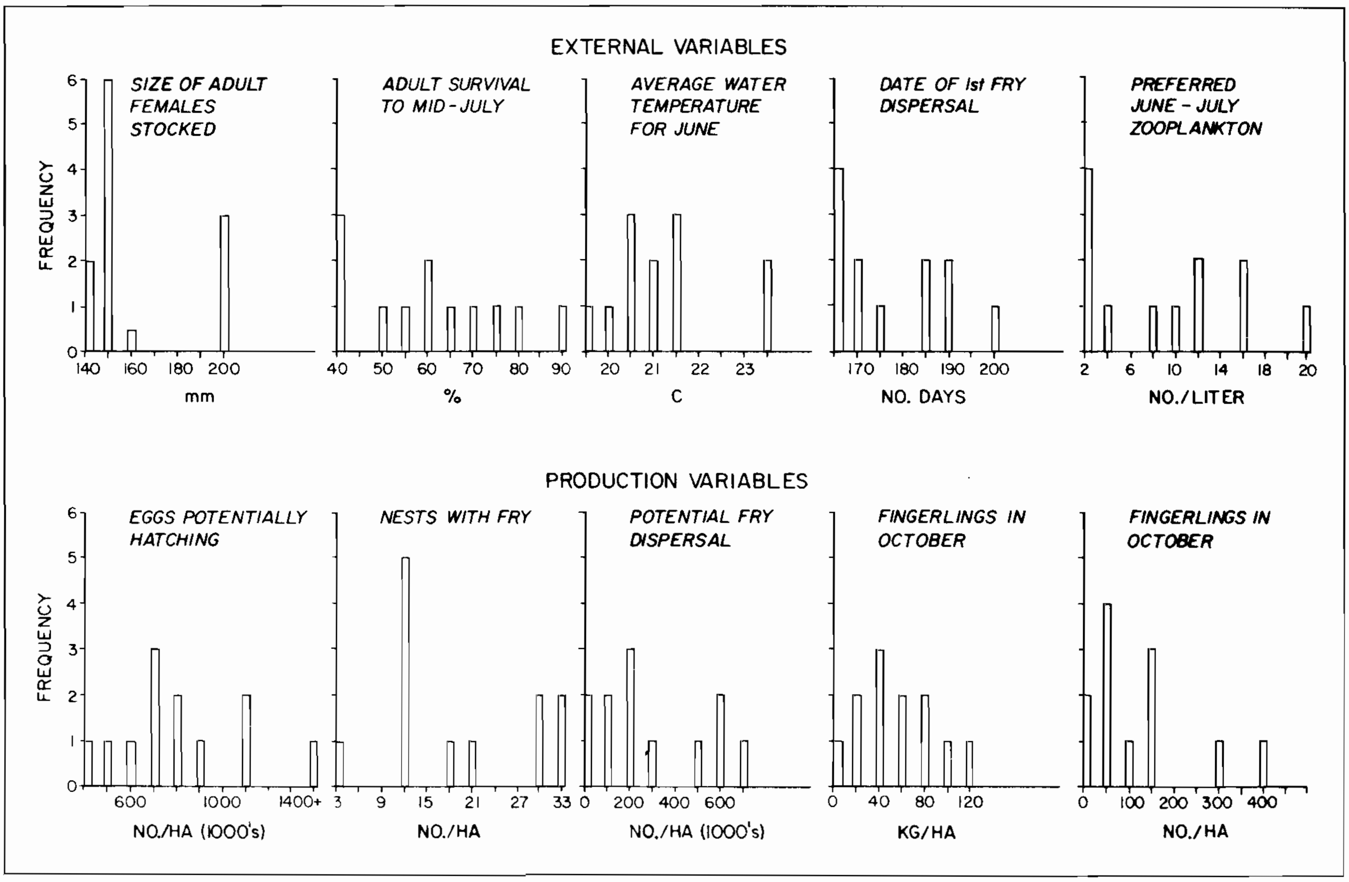
(19) The present study demonstrated that the entire year class of bluegill may be isolated in the limnetic area of a lake for a particular period. It may be possible to reduce the year class at this time by the use of low concentrations of a suitable toxicant in the limnetic regions of the lake.

(20) Two alternatives could be considered for increasing the survival of stocked walleyes. First, stock walleyes the last of June before they change to a fish diet. Second, if the walleyes are held until August, they should be provided with a fish diet. Introducing a forage species into the hatching ponds that will spawn during summer is a suggested method to provide this fish diet.

APPENDIX

APPENDIX TABLE 1. *English-metric conversion factors.*

To Convert	Multiply By	To Obtain
Millimeters	0.03937	Inches
Grams	0.03527	Ounces
Kilograms	2.2	Pounds
Kilograms/hectare	0.892	Pounds/acre
Number/hectare	0.40469	Number/acre
Hectares	2.47	Acres
Centigrade	9/5 (°C+32)	Fahrenheit



APPENDIX FIGURE 1. *Frequency distribution of data in Table 21 by variable.*

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ACKNOWLEDGMENTS

Thanks are given to Donald Stafford and Jon Peterson, fish technicians, who ably assisted in all phases of field work and much preliminary processing of field data. I would also like to thank the following persons who have critically reviewed this manuscript at various stages: from the Ohio Cooperative Fishery Research Unit — Robert F. Carline, Unit Leader; from the Wisconsin Department of Natural Resources — Howard E. Snow, Warm Water Fish Research Group Leader; L. M. Christenson, Fish Research Section Chief; Ruth L. Hine, Research Coordination Section Chief; Donald R. Thompson, Technical Services Section Chief; Eugene L. Lange, Division of Resource Management Biometrician; Cyril Kabat and Kent E. Klepinger, former and present Research Bureau Directors; and John H. Klingbiel, Coolwater Fisheries and Propagation Specialist, Bureau of Fish Management. Finally, special appreciation is given to Betty Les who took a rather lengthy rough draft report, edited it for both content and technical errors, and produced a streamlined readable report; and to personnel from the U.S.F.S. Chequamegon National Forest for their support throughout the study.

This research was supported in part by the Federal Aid in Fish Restoration Act under Dingell-Johnson Project F-83-R. This manuscript represents the Final Report for Study No. 204.

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